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CITRUS SCAB: ITS CAUSE AND CONTROL

By

JOHN R. WINSTON, Pathologist
Office of Fruit-Disease Investigations, Bureau of Plant Industry

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ECONOMIC IMPORTANCE AND DISTRIBUTION OF CITRUS SCAB.

Citrus scab, or verrucosis (also commonly known as lemon scab, sour-orange scab, sour scab, and grapefruit scab), is a parasitic fungous disease of the twigs, leaves, and fruits of many species of citrus.

Citrus scab occurs in India, South China, Formosa, Japan, Hawaii, Paraguay, Brazil, Canal Zone, Yucatan, Texas, Louisiana, Mississippi, Alabama, Florida, Cuba, Isle of Pines, Porto Rico, and the lesser islands of the West Indies. It is also reported as being in the Canary Islands and the Union of South Africa.

In general importance to the citrus industry, citrus scab is second only to the diseases known as melanose and stem-end rot, caused by *Phomopsis citri* Fawcett. It was largely responsible for the failure of the lemon industry in Florida, which prior to the introduction of citrus scab gave promise of becoming a very profitable undertaking.

Throughout the Gulf and South Atlantic regions, wherever citrus fruits are grown, as well as in Cuba, Porto Rico, and the less important citrus districts in the Caribbean Sea, citrus scab has already become very firmly established and doubtless will increase in importance, especially in those localities where the grapefruit industry is important. It is not uniformly serious throughout the citrus-growing sections of the Gulf States, but in certain well-defined localities scab is of the greatest importance.

The damage done to leaves on bearing trees is more unsightly than harmful (Pls. I and II; Pl. III, Fig. 2). There is no tangible evidence to show that the functioning power of moderately affected leaves is seriously impaired.

In orchards where a large proportion of scab has recently developed, especially where the infection is serious enough to cause a marked distortion of the fruit (Pl. III, Fig. 1), the dropping of fruit recently set is considerably greater than where scab does not occur in serious proportions. A large percentage of this dropped fruit is distorted by scab. In addition to the rather intangible financial loss brought about by the abnormal early drop of green fruit due to scab infection, a more tangible loss is occasioned by scabby fruit reaching maturity. A badly blemished fruit is a cull; a slightly blemished fruit has to be sold by the producer at a discount of at least 50 cents per box in years of fair prices. An average estimate made by conservative business men familiar with the citrus industry covering the scab losses to citrus growers in Florida is about 1,000,000 boxes infected annually. With the production of citrus fruits in Florida increasing rapidly, the average annual losses from scab are likely to increase. Under the most favorable circumstances the cost of production of grapefruit, kid-glove oranges, tangelos, and lemons of first quality is greatly increased in districts where scab is a serious factor and has to be controlled by sprays.

The damage done to groves before they come into bearing is considerable, but usually not sufficiently great to render control measures imperative. Nevertheless, a reasonable investment in protective measures may be used to financial advantage.

Scab is the only parasitic fungous disease of consequence occurring in the citrus nursery. There it is extremely serious. It produces a very marked stunting effect upon seedling stocks for budding (Pl. IV), frequently reducing the growth by about 40 to 50 per cent. Where citrus scab is held under control vigorous seedlings are sufficiently large to be budded after having been transplanted to nursery rows for a growing season. Where the disease occurs in quantity and is not held in check by treatment, seedlings may require from 2½ to 3 or more years to make sufficient growth to be budded. This disease is of such serious consequence to rough-lemon and sour-orange nursery stock that nurserymen are in search of a desirable stock immune to citrus scab. Grapefruit leaves are most susceptible to infection as they begin to expand. They become entirely resistant to infection by the time they reach a half inch in width. Fruit is susceptible until it is about three-fourths of an inch in diameter.

SPECIES AND VARIETIES ATTACKED.

Among the commercial species and varieties grown under Florida conditions the sour orange[1] (*Citrus aurantium*) (Pl. V, Fig. 2), lemon (*C. limonia*) (Pl. VI, Fig. 2), calamondin (*C. mitis*) (Pl. VII, Fig. 2), and tangelo (a tangerine-grapefruit hybrid) (Pl. VI, Fig. 1) are extremely susceptible to citrus scab. The grapefruit and shaddock (*C. grandis*); the King orange, tangerine, mandarin orange, and Satsuma orange (Pl. I, Fig. 2; Pl. V, Fig. 1), all of the kid-glove group of oranges (*C. nobilis*) and the citrange (a hybrid of *Poncirus trifoliata* and the tangerine) are quite susceptible to infection. The sweet or round oranges (*C. sinensis*) and kumquats (*Fortunella* spp.) are attacked rarely. The Mexican or Key lime (*C. aurantifolia*) and the Royal and Triumph grapefruits (supposed to be hybrids of the orange and grapefruit) appear to be immune. Data on the susceptibility to citrus scab of the less important species and varieties are being accumulated and will be published later.

Since the grapefruit is the commercial type of citrus most affected by scab in Florida, the statements in this bulletin relate particularly to it unless otherwise indicated. Such grapefruit varieties as the Duncan, Walters, Pernambuco, Leonardi, and Foster are susceptible to infection in about equal degree. Hall (*Silver Cluster*) is much more susceptible and the Marsh considerably less so than the above varieties, and these two can frequently be recognized in mixed plantings simply by the relative proportion of scab present. The Royal and Triumph varieties have never been observed by the writer to be infected.

DESCRIPTION OF THE DISEASE.

On bearing grapefruit trees citrus scab usually confines itself to the leaves and fruits, though occasionally it is observed on the calyx (Pl. VI, Fig. 3) and pedicels of blossoms, and on tender twigs. The extremely susceptible species, such as the sour orange and rough lemon, are affected as specified above, and in addition succulent twigs are frequently affected. In the nursery leaves and twigs of the sour orange and the rough lemon may be attacked severely enough to reduce the annual growth to about 60 per cent of normal (Pl. IV). Grapefruit is similarly affected, but very much less so in frequency of occurrence and in degree of injury.

Leaves.—Scab develops first as minute, more or less circular, distinctly raised protuberances, usually on the under surface of the leaf. In a few days the apices of these fresh lesions become cream-colored or pale yellow-orange and plainly evident to the unaided eye. As the leaf expands (Pls. I and II) these lesions become more conspicuous, some forming hollow, conical outgrowths, the apices

[1] The technical classification of citrus species referred to in this bulletin follows W. T. Swingle (*37*). Serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

of which are scabby lesions, others coalescing to form more flattened scabs. In severe infections numerous lesions cause a serious distortion of the leaf (Pl. VIII, Fig. 1; Pl. IX, Fig. 2), which sometimes drops as a result of the infection. Later, the lesions become warty (Pl. VI, Fig. 4) and assume a pinkish and still later a dirty olivaceous color, largely as a result of invasion by saprophytic fungi.

Fruit.—The incipient stages of citrus scab on the fruit are essentially the same as on the leaf, except that the outgrowths are solid. The lesions soon become cream-colored or pale yellow-orange and decidedly raised, resulting in more or less distortion of the fruit (Pl. III, Fig. 1). In a few months these spots lose their cream color and usually assume a dusty gray hue. On the grapefruit these protuberances when few in number eventually flatten out, and the fruit regains its normal shape (Pls. X and XI). Lesions on the sour orange and the lemon seldom flatten, but ultimately produce ugly, corky, slightly raised warts (Pl. V, Fig. 2; Pl. VI, Fig. 2). The outgrowths on tangelos are higher and more pointed than on grapefruit and do not flatten as the fruit grows (Pl. XII, Fig. 1).

Twigs.—Infection of twigs takes place for the most part on very succulent growth, such as rapidly growing nursery stock and involves only the most susceptible varieties (Pl. VIII, Fig.1; Pl. IX, Fig. 1). The lesions appear as small cream-colored slightly raised warts, later becoming somewhat pinkish and still later taking on a dusty color, due to secondary invaders.

Several types of injury may be confused with citrus scab. Probably the most frequent confusion is between the so-called thrips injury and old flattened scab lesions. The scars produced by the former are never raised and are much smoother than those caused by scab; they frequently have a characteristic silvery sheen, and the position and pattern are usually distinctive. Another type of injury which causes confusion in the field, even to pathologists, is wind injury to young leaves caused by blowing sand or rubbing effects. This condition is found only on trees exposed to sweeping winds in such positions as are found near a wide expanse of open land or a lake front. Frost injury at a distance may also be mistaken for citrus scab. The minute features are quite distinct.

Citrus canker has been confused with citrus scab because of its warty and corky appearance. An individual citrus-canker lesion grows to be much larger than one of citrus scab. It extends much deeper into the spongy tissue of the fruit rind and entirely through the leaves. The canker spots are surrounded by a yellowish oily zone, which is very distinctive. Citrus canker readily attacks succulent twigs of the common varieties of citrus.

REVIEW OF THE LITERATURE.[2]

It is generally recognized in Japan that citrus scab is a native disease of oranges. Scabby oranges were first called by the native names "abata mikan" (smallpox orange), "kasakaki mikan," and "kasa mikan" (both meaning syphilis-scab orange), according to Nishida (*13*)[3] and Ideta (*9*). The disease is now called "sôkabyô" (Fig. 1, *a*, scab disease), first proposed by Nishida (*14*) in accordance with the American name "citrus scab." This name, however, included not only citrus scab but also citrus canker until the latter was separated by the terms "marugata sôkabyô" (Fig. 1, *b*, round scab disease) and "kankitsu kwaiyobyô" (Fig. 1, *c*, canker disease of citrus) (*29*, p. 7–9).

Probably the earliest mention of citrus scab in Japanese literature is in a manuscript work called "Nankai Hofu" (oranges of the South Sea district) written by Yoshiyuki Murase in 1818. Two kinds of scabby orange were given, with the Chinese names "shitôkan" (Fig. 1, *d*, shih t'ou kan, lion-head orange) and "reishikitsu" (Fig. 1, *e*, li chih chu, lychee orange), the latter bearing the popular name "kasa mikan." These two were illustrated in the "Honzo Dzufu" of Tsunemasa Iwasaki, completed in 1828 (*10*, book 62, fol. 7 and 11). In these early works scabby oranges are treated as particular kinds and not as diseased fruits. It was first proved by Onda (*15*) that the disease was controlled under Japan conditions by spraying with Bordeaux mixture, but according to Hori (*8*, p. 281–282) the disease was given no particular attention by citrus growers until about 1905, when they recognized its disadvantage in connection with the exportation of the Satsuma orange.

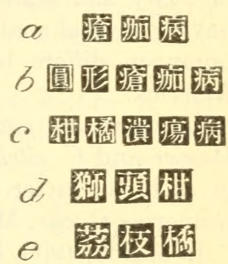

FIG. 1.—Japanese characters for citrus diseases and their hosts: *a*, Sôkabyô; *b*, marugata sôkabyô; *c*, kankitsu kwaiyobyô; *d*, shitôkan; *e*, reishikitsu.

The first report on citrus scab in America was made by Scribner (*19*), who stated that the disease first made its appearance in America in 1885 on sour-orange stock in a citrus nursery near Ocala, Fla. In 1886 it was attacking lemon trees. In a later publication (*20*) on the subject, accompanied by a colored plate of gross and microscopic features, he attributes the disease to a species of Cladosporium, without describing it.

Underwood (*30*, p. 34) confirmed Scribner's findings and reported the disease as occurring very commonly on wild (sour) oranges, frequently on grapefruit and lemon trees, and rarely on sweet-orange trees.

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[2] The abstracts of the Japanese literature on citrus scab were made by Dr. Tyôzaburô Tanaka, of the Office of Crop Physiology and Breeding Investigations, Bureau of Plant Industry.

[3] Serial numbers (italic) in parentheses refer to "Literature cited" at the end of this bulletin.

Swingle and Webber (*28*, p. 20–24) were the first to conduct extensive field studies and spraying experiments for the control of scab. They attribute its cause to a species of Cladosporium and state that so far as is known this fungus is found only on citrus plants affected by this disease. A description of this fungus and spore and hypha (sporophore?) measurements are recorded, as well as the varieties attacked and conditions under which infection takes place. They consider that this disease was undoubtedly introduced into America on the Satsuma orange (budwood) from Japan. Copper sprays were found effective against this disease.

Massee (*12*, p. 310–311) attaches the specific name "*citri* pro tem." to the generic name Cladosporium, not for final acceptance but for convenience in reference. He gives Swingle and Webber's measurements of spores and sporophores and adds a brief description of their form. Briosi and Farneti (*1*) describe the ruggine bianca of lemons in Sicily and state this disease is caused by *Rhynchodiplodia citri*, having several conidial forms, among them *Cladosporium citri*. This organism differs but little from *C. citri* occurring in Japan and America.

In order to correct the confusion between *Cladosporium citri* Massee and *C. citri* Briosi and Farneti, Saccardo (*18*, p. 1366–1367) gives to the latter species the name *C. farnetianum* and records the former as *C. citri* Massee.

In March, 1906, Fawcett (*2*) isolated a hitherto undescribed fungus from sour-orange leaves. He made mention of certain of its cultural characters and used the name *Cladosporium citri* in connection with this new organism. In a later publication (*3*) he calls attention to a series of errors which had crept into the literature in regard to the confusion of *C. elegans* Penz. with *C. citri* pro tem. Massee. Still later Fawcett (*4*) proved by a series of inoculations that the scab is caused by the fungus found by him in scab lesions as early as March, 1906. The characters of this true citrus-scab organism were illustrated and again described. Unfortunately this pathogen was left without a name to distinguish it from the saprophytic organism illustrated by Scribner (*20*) and described by Swingle and Webber (*28*, p. 20–24) and by Massee (*12*, p. 310–311). The result is that two organisms, very distinct in morphological and cultural characters (the one a true parasite, the other a saprophyte) have been referred to in the literature as *Cladosporium citri* Massee. Attempts to find a perfect stage of the true citrus-scab fungus were made by Fawcett without success. Citrus plants subject to attack by this fungus are mentioned and control measures based on spraying experiments suggested.

Stevenson (*24*) emphasizes the influence of weather on citrus-scab outbreaks. His experiments for control show that in Porto Rico (*26*) sulphur sprays were partially effective against citrus scab, while

Bordeaux mixture gave satisfactory control (*25*) and sulphur dusts no control of this disease.

Grossenbacher (*7*) lists susceptible species in Florida and discusses conditions favoring citrus-scab outbreaks. His attempts to produce the disease artificially failed, undoubtedly because he used cultures of the saprophytic *Cladosporium* sp. which develops on old citrus-scab lesions rather than the active pathogen first isolated by Fawcett. Bordeaux mixture proved to be much more effective than lime-sulphur solution against citrus scab. Spraying after the middle of May was found to be too late for effective citrus-scab control. He advises one application of Bordeaux mixture in the height of the bloom, followed in a week or 10 days by an application of lime-sulphur solution and still another application of lime-sulphur solution two or three weeks later.

Fawcett (*5*) reports further confirmative inoculation experiments in producing typical scab lesions by using the true scab organism. He further discusses the confusion of this organism with the common saprophytic Cladosporium.

Lee (*11*) reports finding citrus-scab lesions on leaves of *Citrus nobilis* collected by Maximowicz in 1863 at Nagasaki and deposited in the herbarium of the Hongkong Botanic Gardens. This observation coupled with the fact that scab is distributed throughout the citrus-growing section of South China led him to conclude that this disease may be indigenous to the Orient.

Stevens (*22*) found in avocado-scab lesions an organism in every morphological and cultural character similar to the citrus-scab fungus. With the avocado-scab fungus he produced typical scab lesions on the avocado as well as on the citrus, but the fungus isolated from lesions on citrus failed to infect the avocado. In a later publication (*23*) he predicts that scab will eventually be as severe on the round orange as it is now on the grapefruit.

Fawcett (*6*) reports the results of experiments to determine the effect of constant temperatures on infection of sour-orange leaves and on the vegetative growth and spore development of the citrus-scab fungus. Infection on rapidly growing parts occurred between 16° and 23° C, while detached leaves floated in water were infected at temperature ranging from 16° to 27.5° C. Vegetative growth was most rapid at 21° C. Spores developed at all temperatures from 13.5° to 27.5° but not at 32° C. At 21° C. the spore development was more abundant than at lower or higher temperatures. In the light of these experiments Fawcett thinks the relatively low temperatures of spring tend to aid and the high temperatures of summer in Florida to retard or inhibit infection.

THE CAUSAL ORGANISM.

Citrus scab is caused by a fungus originally isolated by Fawcett (*2*) in 1906 and referred to by him as *Cladosporium citri* Massee. In subsequent publications by various workers the pathogen is referred to by this binomial. This organism (Pl. XIII) has none of the distinctive characteristics of Cladosporium Link. A saprophytic species of Cladosporium develops almost invariably in old citrus-scab lesions and becomes very conspicuous after several months of weathering or after the true scab fungus has largely disappeared. Inoculation tests conducted by the writer at Orlando, Fla. (Table 9), with this saprophytic Cladosporium have given no evidence of any pathogenicity. Since the mycological position of the causal organism has not been established it will be referred to in this bulletin as the citrus-scab fungus, and certain of its cultural and morphological characters will be described to aid in diagnosis.

Its growth on certain nutrient media is characteristic (Pl. VII, Fig. 1), so much so that it can be readily recognized from such reactions. In general the fungus grows slowly, requiring from five to eight days at room temperature for colonies to become plainly visible. When scrapings are made from relatively young lesions very few contaminations develop in the poured plates. Isolations from old lesions which have been overrun by the common saprophytic Cladosporium are more difficult.

One of the best media for isolation and differentiation is glycerine agar. On this medium the fungus produces a distinct purplish color reaction which often becomes plainly visible before growth characters are advanced enough to be distinctive. The prominent growth characters as they appear on the more common media, together with their color reactions, are here given. For convenience in reference to the colors and shades Ridgway's (*17*) standard is used as a basis of comparison, and his plates are indicated by numbers preceded by the symbol R.

PROMINENT GROWTH CHARACTERS.

MOLISCH AGAR SLANTS (FORMULA 1).

Age 7 days: Growth moderate, about 3 millimeters in diameter, restricted, raised about 1 millimeter, convoluted; medium slightly penetrated.

Age 15 days: Growth moderate, about 1 centimeter in diameter, restricted, raised about ½ centimeter, occasionally center of colony more or less villous, convoluted; medium irregularly penetrated but not discolored.

Color of fungus: Ochraceous tawny to cinnamon brown (R 15).

POTATO DEXTROSE AGAR SLANTS (FORMULA 2).

Age 7 days: Growth moderate, about 4 millimeters in diameter, restricted, raised about 3 millimeters; numerous small warts becoming whitish with woolly hyphæ.

Color of fungus: Light ochraceous salmon (R 15) to pallid vinaceous drab (R 45).

Age 15 days: Growth moderate, about 1 centimeter in diameter, restricted, raised about 0.5 centimeter; numerous small warts covered with pale woolly hyphæ irregularly penetrated and rendered dusky auricula purple near colonies.

Color of fungus: Vinaceous buff (R 40) to pallid purple drab (R 45).

BEEF AGAR SLANTS (FORMULA 3).

Age 7 days: Growth moderate, about 5 millimeters in diameter, restricted, round, warty.

Color of fungus: Wood brown.

Age 15 days: Growth moderate, about 7 millimeters in diameter, restricted, raised; center warty, edges distinctly convoluted; media color unchanged.

Color of fungus: Clay (R 29) to ochraceous tawny (R 15).

GLYCERIN AGAR (FORMULA 4).

Age 7 days: Growth scant, about 1.5 millimeters in diameter, restricted, center raised, villous, border flattened; medium slightly penetrated.

Color range of media and fungus: Perilla purple (R 37) to pale purple-drab or pallid vinaceous drab (R 45).

Age 15 days: Growth poor, about 5 millimeters in diameter, restricted, raised; covered with dense, short woolly hyphæ, border flattened, villous; medium moderately penetrated.

Color of fungus: Pallid vinaceous drab (R 45). Media close to colonies, Corinthian purple (R 38) to dull Indian purple (R 44).

TOMATO AGAR (FORMULA 5).

Age 7 days: Growth moderate, about 3 millimeters in diameter, restricted, raised, convolute; medium irregularly penetrated.

Color of fungus: Ochraceous tawny (R 15) to wood brown (R 40) or pale vinaceous drab (R 45).

Age 15 days: Growth good, about 1 centimeter in diameter, restricted, raised, warty, covered with dense, short woolly hyphæ; medium irregularly penetrated, medium color unchanged.

Color of fungus: Pallid vinaceous drab (R 45) to light cinnamon drab (R 46).

MEDIA FORMULAS.

The media used in these cultural studies were made according to the following formulas, titrated to Fuller's scale, using phenolphthalein as indicator, and autoclaved at 15 pounds pressure.

Formula 1. Molisch medium (*21*, p. 198) modified (acidity 7): Water, 1,000 cubic centimeters; agar agar, 20 grams; cane sugar, 20 grams; peptone, 10 grams; dipotassium phosphate, 25 grams; magnesium sulphate, 25 grams.

Formula 2. Potato-dextrose agar (acidity 12): Water, 1,000 cubic centimeters; white potatoes, 500 grams; dextrose, 20 grams; agar agar, 20 grams.

Formula 3. Beef agar (acidity 10): Water, 1,000 cubic centimeters; agar agar, 20 grams; peptone, 10 grams; beef extract, 3 grams; sodium chlorid, 5 grams.

Formula 4. Glycerin agar (neutral): Water, 1,000 cubic centimeters; glycerin, 20 cubic centimeters; agar agar, 20 grams.

Formula 5. Tomato agar (acidity 15): Fresh ripe tomato juice, 200 cubic centimeters; water, 1,000 cubic centimeters; agar agar, 24 grams.

In addition to these media, the fungus has been grown on corn-meal agar, prune agar, nitrogen-free agar; on clover stems, bean pods, and orange stems; and on celery, carrot, tomato, bean, peach, apple, and prune broths.

DEVELOPMENT OF SPORES.

True conidia (Pl. XIII, Fig. 9) are borne very sparingly in culture, so much so that they are not considered in this bulletin. Secondary colonies developing in test tubes are rather unusual. As cultures age the convoluted mycelium rapidly becomes thick-walled and develops tangled chains of more or less regularly constricted hyphæ. These convoluted chains are easily broken apart into many single-celled thick-walled bodies, apparently chlamydospores, which possess the power of germination (Pl. XIII, Figs. 1 to 7) and which are most likely responsible for the greater part of the infections induced by artificial inoculations from cultures.

TEMPERATURE RELATIONS.

In order to determine the effect of temperature upon the radial growth of the citrus-scab fungus on artificial media a relatively large number of cultures were held for 42 days at various temperatures. In each tube a bit of fungus tissue not more than 0.5 of a millimeter in diameter was planted as near as possible in the center of the slant surface. The media used were potato-dextrose agar, glycerin agar, beef agar, and Molisch agar. The strains used were isolated from various susceptible citrus varieties, but no appreciable variation could be noted between the several cultures. The average final diameter of colonies on the several media is the basis of comparison of growth as here recorded in Table 1.

TABLE 1.—*Growth of citrus-scab fungus attained in 42 days at various temperatures.*

Colonies.	Temperatures (° C.).							
	0	5	15	20	18 to 25 (room range).	28	36	45
Diameter................millimeters..	1	2	8	10	12	7	2	0

It will be seen that around 20° C. (68° F.) is probably the optimum temperature for the development of the fungus in culture. This in a measure may account for the relatively large proportion of citrus-scab infection which occurs during the cool weather of spring. Nevertheless an abundance of infection occurs in the hot summer months as well.

OVERWINTERING.

In order to determine whether or not the citrus-scab fungus lives over winter on fruit or leaves, or both, a number of isolation tests were made at various times during the past four years. Invariably an abundance of scrapings from citrus-scab lesions not previously disinfected were placed in sterile Petri dishes, covered with glycerin agar or potato-dextrose agar, and held at room temperature for 10 or 15 days before making final records. Table 2 gives the result of these isolation tests made for the most part in the laboratory at Orlando, Fla.

TABLE 2.—*Results of isolation tests of citrus-scab fungus from citrus fruit and leaves.*

TESTS OF LEAVES.

Date of isolation.	Host.	Growth developed.	Remarks.
Dec. 11, 1916	Grapefruit	Spring, 1916	Very many colonies.
Do	Round orange	do	Many colonies.
Feb. 14, 1917	Grapefruit	October, 1916	Very many colonies.
Feb. 15, 1917	King orange	Spring, 1916	Do.
July 27, 1917	Satsuma orange	Spring, 1917	Do.
Feb. 10, 1918	Sour orange	do	Many colonies.
Do	Rough lemon	do	Do.
Do	Grapefruit	do	Do.
Feb. 20, 1919	Sour orange	Spring, 1918	Very many colonies.
Do	Rough lemon	do	Do.
Do	Grapefruit	do	Do.
Feb. 10, 1920	Tangelo	Summer, 1919	Do.
Do	Calamondin	do	Do.
Do	Sweet bittersweet	do	Do.
Oct. 24, 1920	do	Spring, 1920	Many colonies.
Nov. 5, 1920	Sour orange	do	Do.
Nov. 19, 1920	do	do	Do.
Feb. 6, 1921	Grapefruit	do	Do.
Mar. 8, 1921	do	do	Do.
May 9, 1921	do	do	Do.

TESTS OF FRUIT.

Date of isolation.	Host (grapefruit).	Fruit set.	Remarks.
Feb. 15, 1917	$\frac{3}{4}$-inch diameter	December, 1916	Very many colonies.
May 27, 1920	Green, $1\frac{1}{2}$ inches diameter.	March, 1920	Do.
June 10, 1920	Green, 2 inches diameter.	do	No colonies.
June 23, 1920	$2\frac{1}{2}$ inches diameter	do	Do.
Do	do	do	Do.
July 20, 1920	$3\frac{1}{2}$ inches diameter	do	Do.
Oct. 24, 1920	Half colored	do	Do.
Nov. 5, 1920	do	do	Do.
Nov. 19, 1920	Three-fourths colored	do	Do.
Feb. 6, 1921	Mature	Spring, 1920	Do.
Mar. 8, 1921	do	do	Do.
Mar. 9, 1921	do	do	Do.
July 23, 1918	Ripe	December, 1917	Do.
Feb. 10, 1920	do	December, 1919	Do.

These tests show that when once the scab fungus enters a leaf, it can persist there throughout the winter. This finding is corroborated by a large number of field observations in which new flushes developing in close proximity to hold-over lesions were seriously affected by scab while more distant flushes were scab free.

The isolation experiments further show that the causal organism does not persist for any great length of time in fruit. It seems reasonable to conclude from cultural data and field observations that the disease is seldom if ever carried over winter on fruit set in the spring or summer.

PATHOLOGICAL ANATOMY.

Microscopic examinations of the lesions, especially those on leaves, show that the fungus forms a compact stroma of convoluted thick-walled hyaline mycelium. From this base numerous hyaline sporophorelike bodies arise, but as yet the writer has not found spores attached to these specialized hyphæ. Beneath the stroma a rather loose, coarse, thick-walled hyaline mycelium penetrates the host intercellularly for a distance of several cells. The host tissue in close proximity to the fungus rapidly becomes brown and distorted. Distinct hyperplasia is often in evidence beneath the area attacked by the fungus, which fact probably accounts for the plainly evident excrescence associated with scab lesions (Pl. XIV).

Specialized host tissue can frequently be found separating the invaded from the uninvaded parts. This condition occurs in older leaves. It has not been observed in leaves incompletely expanded.

As the leaf ages, secondary fungi, principally Cladosporium and Colletotrichum species, invade the lesion and soon partially mask the pathogen. This invasion may take place within a few days after primary infection occurs, but usually does not become very evident until the lesions are several weeks or months old. The older the lesion becomes the less conspicuous the causal organism appears. Frequently the stroma which was conspicuous in young scars disappears by fall or winter, leaving only fragmentary bits of the pathogen on the host. The stroma which persists in citrus-scab lesions through the winter becomes especially thick walled. When that stroma is placed under the microscope and a slight pressure exerted on the cover slip the fungal mass frequently separates into many thick-walled single-celled bodies, indicating that under certain natural conditions this stroma may possibly be separated into many sporelike bodies.

DISSEMINATION OF THE CAUSAL FUNGUS.

The agencies employed in the dissemination of the citrus-scab fungus are doubtless the same as those that aid in the spread of most diseases. Frequent relatively high winds accompanied by stormy periods occur in the spring about the time the leaves or fruit are susceptible to infection. A large number of observations have indicated that storms play an important part in spreading the fungus from tree to tree. This dissemination of the fungus from infected trees, however, is hardly comparable with the distinct path of invasion made by such diseases as cedar rust or scab of apple. The spread of citrus scab is very erratic. It may persist for a number of years on a small group of trees or even a single tree without increasing its distribution, or it may spread very gradually over an orchard, or it may suddenly become pandemic over a large, hitherto apparently scab-free, isolated property. On the whole, the fungus is gradually gaining entrance into sections hitherto free from this disease and in many places increasing where already established.

The exact part of the fungus concerned in dissemination is questionable. Most writers attribute it to spores produced in scab lesions. In order to determine this point, a great many microscopic examinations were made of old and young scab lesions at various times during the past four years, especial attention being given to it during periods of scab outbreaks. Hundreds of sections were examined, but in no instance were conidia of the causative organism found. That the fungus was present and alive in both the old and young lesions at the time of microscopic examinations was proved repeatedly by cultural methods.

There appear to be no available data to show that the fungus in such lesions produces conidia in sufficient numbers to account for the widespread and rapid primary infections occurring under favorable conditions. At various times attempts were made to find a perfect stage of the causal organism. These efforts were futile.

Attention is called elsewhere to the gross appearance of the fungus in citrus-scab lesions on leaves and to the ease with which the fungal mass is divided into many thick-walled single-celled bodies called chlamydospores which are doubtless responsible for a great part of the primary infections occurring in early spring.

In addition to old lesions abundantly supplied with a hold-over stroma, many scars occur in which the stromatic mass has weathered away. There is a marked flaking off of host and fungal (mycelial) fragments from such lesions during the early spring, so much so that pure cultures can be isolated easily from such scales by holding an affected leaf over an open Petri dish and brushing the lesions. This indicates that spring infection in part at least may be attributed to fragments of host and parasite flaking from these lesions.

Regardless of whether the disease starts in the spring from chlamydospores or fragments of host and fungus, there is no tenable evidence to show that citrus scab is spread for the most part by conidia produced in these old lesions.

CONDITIONS INFLUENCING INFECTION.

Local and seasonal conditions play an important part in the dissemination and propagation of this disease. In years of rainy springs citrus scab is almost certain to be severe on grapefruit, provided the rainy periods occur while the leaves or fruit are in a stage of development susceptible to infection. It is a matter of common remark among growers that citrus scab is very likely to be serious if rainy spells occur during or soon after the blossoming period.

If the vegetative flush precedes the opening of the bloom during weather that is then dry and warm very little infection is likely to occur on leaves, but should rainy weather occur during or soon after the bloom, the fruit is likely to be infected though the leaves escaped. If the weather reverses its order the leaves are likely to be infected and the fruit remain free from scab.

In localities where heavy dews or fogs occur normally during the critical period, or in orchards on low hammocks or flatwood soils, which are usually damp locations, scab is commonly quite severe even during springs of minimum rainfall; and the June bloom fruits, as well as the leaves expanding during the rainy season, are almost always very severely attacked. In the high, dry rolling hill country citrus scab is a negligible factor during ordinary years and only becomes serious during years which are unusually favorable for its development. Ordinarily in such localities the June bloom fruit is only moderately affected, if at all.

In a very excellent article, Fawcett (*6*), among other data, gives the results of inoculations with the citrus-scab fungus held at definite maintained temperatures together with a statement of the failure of inoculations made in Florida during August under natural conditions and the success of those made in January. He concludes that other factors being favorable natural infection is largely dependent upon temperature ranging from 16° to 23° C. (61° to 73° F.); that infection is likely to occur when the mean temperatures are well within that range and unlikely to take place when the mean temperatures are outside of that range. He says:

> In the light of these temperature experiments, the greater severity of scab at low temperatures in Florida seems to be due largely to the fact that these temperatures fall mainly within the range for infection, while the later spring and summer temperatures are usually too high for infection to take place, even though other conditions are favorable. . . . This last statement may be translated into terms of mean temperatures, to the effect that severe infection will usually occur when the mean temperatures are well within the infection range and that infection will be unlikely to take place when the mean temperatures are outside this range.

Such a conclusion is doubtless in a measure correct, but it is by no means entirely in keeping with the normal behavior of the disease on the several citrus hosts. On the same tree June bloom grapefruit is frequently more severely attacked than that resulting from the spring bloom. Citrus scab attacks nursery stock equally if not more severely in the hot summer months than is the case during the cooler seasons. This is to be expected, since even in warm months the night temperatures usually drop within the optimum range indicated by Fawcett.

In recent years in Florida citrus scab was most prevalent during the seasons of 1914 and 1915 and least so during 1921. A study has been made of the precipitation and mean temperatures at Orlando during the months of January, February, March, and April of the years 1914, 1915, and 1921. These are presented in Table 3.

TABLE 3.—*Mean temperature and precipitation at Orlando, Fla., during the months of January, February, March, and April in the years 1914, 1915, and 1921.*

[Temperature data are stated in degrees F., precipitation data in inches.]

Year.	January.				February.			
	Temperature.		Precipitation.		Temperature.		Precipitation.	
	Mean.	Departure from normal.	Total.	Departure from normal.	Mean.	Departure from normal.	Total.	Departure from normal.
1914	69.4	+0.2	5.23	+2.83	62.2	+1.0	3.31	+0.62
1915	58.7	− .5	4.36	+1.96	60.3	− .9	4.34	+1.65
1921	63.7	+3.5	.52	−2.08	64.1	+2.6	1.76	− .89

Year.	March.				April.				Total departure from normal.	
	Temperature.		Precipitation.		Temperature.		Precipitation.			
	Mean.	Departure from normal.	Total.	Departure from normal.	Mean.	Departure from normal.	Total.	Departure from normal.	Temperature.	Precipitation.
1914	62	−5.6	2.10	−0.20	72.9	+2.1	2.25	+ .29	− 2.3	+3.54
1915	59.2	−8.4	1.41	− .89	68.4	−2.4	.10	−1.10	−12.2	+1.62
1921	73.2	+5.8	.87	−1.44	72.6	+1.5	1.51	− .82	+13.4	−5.23

It will be noted that the mean temperatures for all three seasons are reasonably well within the infection range mentioned by Fawcett, while the rainfall was above normal during 1914 and 1915, years of citrus-scab abundance, and considerably below normal for the same period in 1921, when citrus scab was very slight. Figure 2 shows the daily range of temperature and the precipitation during these four months of 1915, while Figure 3 is a thermographic record [4] for a representative week during the scab season. Figure 4 gives the temperature range during the comparatively scab-free spring of 1921. With the progress of the rainy season of the summer of 1921 numerous complaints were registered in regard to a severe citrus-scab outbreak on the current crop of June bloom fruit, especially on trees which showed little or no spring infection but abundantly supplied with affected leaves from the 1920 growth. Many nurseries which were only slightly affected with scab during the spring of 1921 were very severely attacked during the summer of that year. It thus appears that infection is possible over a wide range of temperatures, and that moisture conditions during periods when young flushes are putting out determine in the main the seasonal prevalence of citrus scab.

Conclusions regarding the general behavior of the disease on its several hosts when based on the behavior of the disease on bearing

[4] The graphs shown in Figures 3 and 6, while not dependable for maximum and minimum range, give a rather accurate account of the length of time that the high and low temperatures were maintained.

grapefruit are likely to be misleading. Rough-lemon and sour-orange nursery trees are exceedingly susceptible to scab infection and are equally affected if not more severely attacked during the hot rainy summer season than is the case in the spring. That this condition exists is corroborated by letters on file in the Office of Fruit-Disease Investigations from five of the larger commercial nurseries in Florida.

The United States Department of Agriculture maintains a nursery of rough-lemon, sour-orange, and grapefruit seedlings at Orlando, Fla., for experimental purposes. This nursery was set out in March, 1918. The flushes which developed during April and May of that year

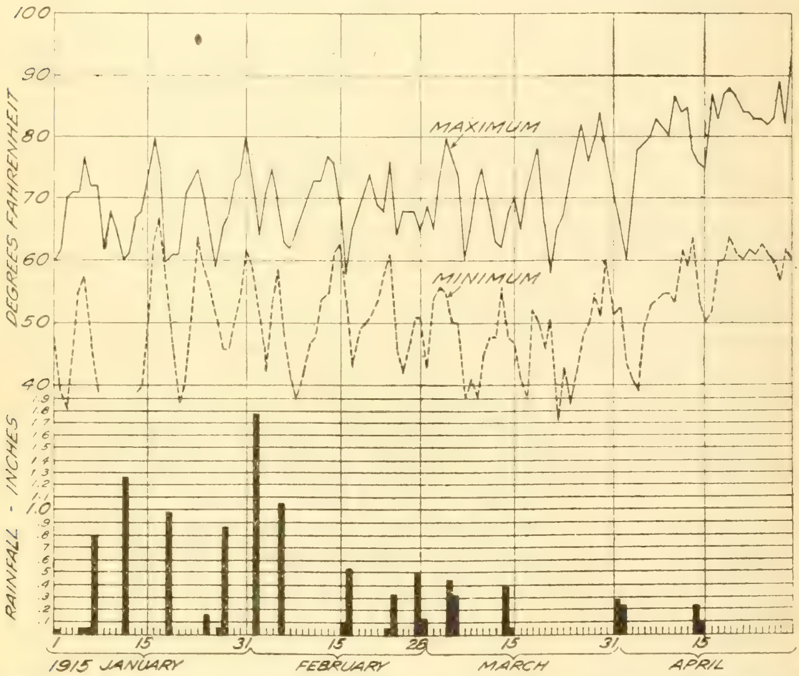

FIG. 2.—Precipitation and maximum and minimum temperatures at Orlando, Fla., during January, February, March, and April, 1915—a year of severe scab infection.

were affected by citrus scab, but not nearly so severely as was the case during the rainy summer weather. The flush which developed late in the fall was comparatively free from citrus scab, in spite of foci of infection on the older leaves. Similar conditions were noted in this nursery during the years of 1919 and 1920, viz, scab attacks the nursery stock more severely during the rainy season in summer than is the case during the spring or fall. As stated in another place, the spring of 1921 was quite dry. Little or no citrus scab developed in this nursery during that period. The same applies to a new seed bed of similar seedlings. As soon as the rains set in citrus scab immediately became severe in this seed bed and increased rapidly in the nursery.

During 1916, 1917, 1918, 1919, and 1920, the outbreaks of citrus scab in the bearing grapefruit orchards of Florida were in approxi-

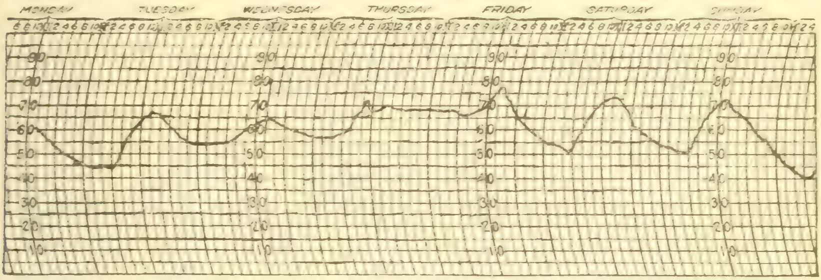

FIG. 3.—Thermographic record of a typical week during the scab infection period, Orlando, Fla.

mately average proportions, varying considerably from one locality to another. These outbreaks were very sporadic and, with but few exceptions, could not be anticipated. Often the disease did not

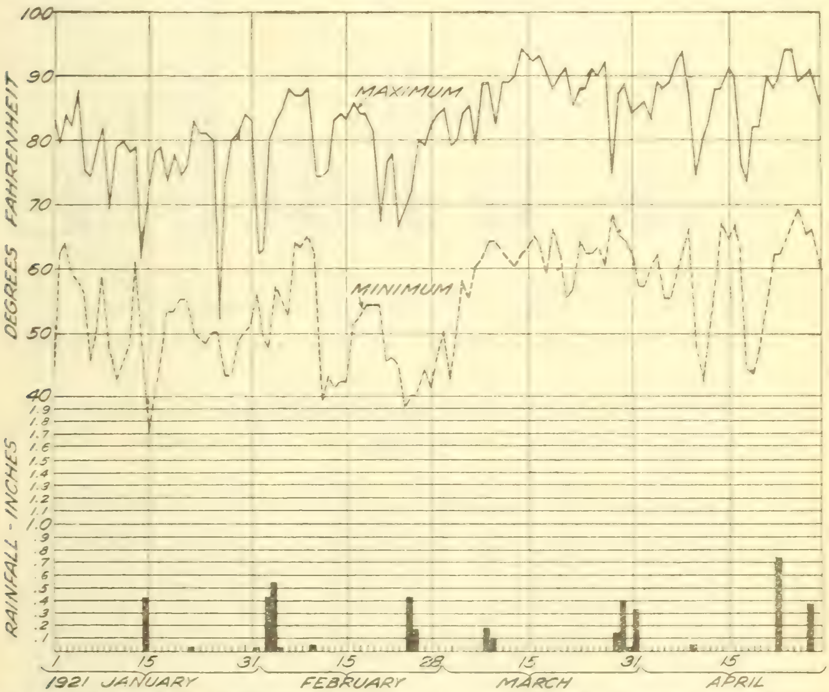

FIG. 4.—Precipitation and maximum and minimum temperatures at Orlando, Fla., during January, February, March, and April, 1921—a year of very little scab infection.

develop in orchards with an abundance of scab on the old leaves, but became rather prevalent in properties hitherto apparently free from scab. On the other hand, sour-orange and rough-lemon nursery stock became severely affected during the spring of those years.

The only apparent explanation for this condition is that the rainy periods were not of sufficient proportion or duration at the proper time to be responsible for general outbreaks in orchards. However, in certain localities the proper timing of the necessary factors for com-

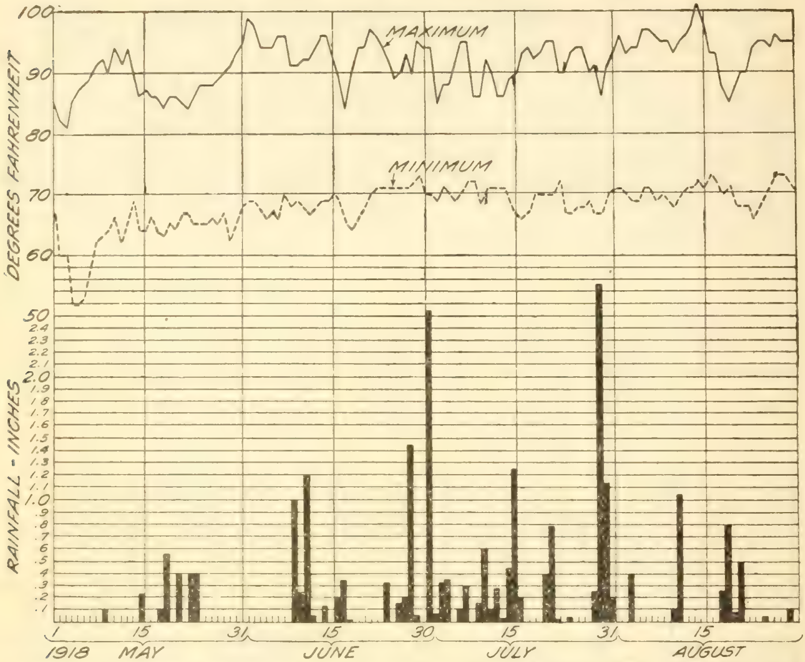

FIG. 5.—Precipitation and maximum and minimum temperatures at Orlando, Fla., during May, June, July, and August, 1918—a period when scab infection was very severe in the nursery.

plete infection doubtless occurred and may account for the irregularity of outbreaks.

Figure 5 gives the temperature range and rainfall at Orlando, Fla., during the months of May, June, July, and August, 1918. Table 4

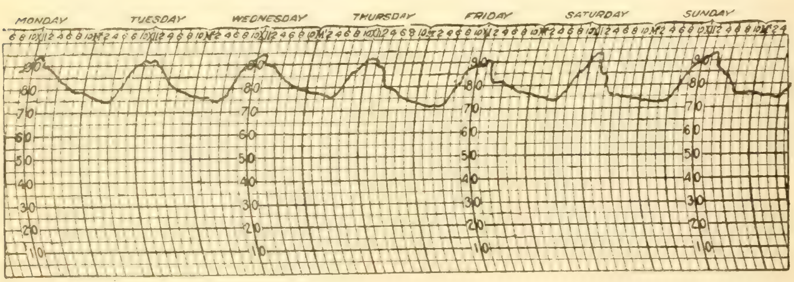

FIG. 6.—Thermographic record of a typical week in summer at Orlando, Fla.

gives similar data for that period of months during 1918, 1919, and 1920, while Figure 6 shows a thermographic record for a representative week.

TABLE 4.—*Mean temperature and precipitation at Orlando, Fla., during the months of May, June, July, and August in the years 1918, 1919, and 1920.*

[Temperature data are stated in degrees F., precipitation data in inches.]

Year.	May. Temperature. Extremes. Maximum.	Minimum.	Mean.	Departure from normal.	May. Precipitation. Total.	Departure from normal.	June. Temperature. Extremes. Maximum.	Minimum.	Mean.	Departure from normal.	June. Precipitation. Total.	Departure from normal.
1918	87.9	63.1	75.5	−1.4	2.11	−1.7	93.2	68.8	81.0	+0.6	5.37	−1.89
1919	89.3	63.2	76.2	−.7	10.37	+6.56	90.5	68.3	79.4	−1.0	5.19	−2.07
1920	84.3	60.8	72.6	+1.6	6.72	+4.70	91.2	67.8	79.5	−.9	5.89	−1.27

Year.	July. Temperature. Extremes. Maximum.	Minimum.	Mean.	Departure from normal.	July. Precipitation. Total.	Departure from normal.	August. Temperature. Extremes. Maximum.	Minimum.	Mean.	Departure from normal.	August. Precipitation. Total.	Departure from normal.	For 4 months. Departure from normal. Temperature.	Precipitation.	Mean temperature.
1918	90.8	69.4	80.1	−0.2	12.[illegible]	+5.5	94.1	70.2	82.2	+0.1	3.34	−3.81	−0.9	−1.9	79.7
1919	92.4	70.3	81.4	−.7	11.49	+4.24	94.[illegible]	70.5	82.4	+.5	5.49	−1.69	−2.1	+6.04	79.8
1920	92.7	70.4	81.6	−.5	7.49	+.24	93.3	69.6	81.4	−.7	5.35	+1.8	−.5	+5.37	78.77

It will be noted that in spite of the fact that the mean temperature is in general well above the limits set by Fawcett, the mean minimum temperatures for summer are usually well within that range, but it is probable the temperature does not remain in that lower zone sufficiently long for infection to progress at a rapid rate.

If it is assumed that the pathogen is present in quantity, there are three other factors which play their parts in completing infection, viz, (1) suitable temperature limits, (2) abundant moisture, and (3) host parts in a stage of development susceptible to infection. The relative scarcity of citrus scab in both orchards and nurseries situated in the drier sections of Florida and in the drier seasons, together with the fact that citrus scab has not been able to establish itself in California lemon orchards with their drier climatic conditions, is strong evidence that this fungus is largely dependent upon certain weather conditions to cause infection, namely, abundant moisture during the period when leaves are expanding and fruit is setting. Such weather seldom occurs in the relatively dry citrus regions of California at times when the plant is susceptible to infection; hence, the absence of scab and its resulting financial losses. Under Florida conditions the normal temperatures occurring throughout the growing months seem to be suitable for infection and for the most part enough moisture is present to allow infection of very susceptible species. Unless the host is in the proper stage of development when there is an abundance of moisture, natural infection does not occur; hence, for practical purposes, it is reasonable to conclude that under average Florida conditions moisture rather than temperature is the important limiting factor in natural infection.

GROWTH HABITS OF GRAPEFRUIT.

A brief consideration of the habits of growth of grapefruit trees under Florida conditions, together with an account of climatic conditions occurring during the periods that a tree is susceptible to infection by the scab fungus, will no doubt aid materially in establishing a reasonable explanation of the behavior of the disease in nature.

Bearing grapefruit trees in the neighborhood of Orlando, Fla., normally produce three distinct flushes of growth during the year. The first growth comes out relatively slowly but uniformly over the tree, usually during February, but in the southern part of Florida it may be as early as January and considerably later at more northern points. The emerging of blossom buds may be the first signs of growth, or vegetative growth and blossom buds may come out simultaneously, or vegetative flushes may partially harden and then develop blossoms on this new wood (Pl. I, Fig. 1).

If the weather is warm and conducive to the active growth of citrus trees there is a comparatively short time between the first signs of growth and the falling of petals from the latest blossoms, but if the weather is cold, rainy, and otherwise unfavorable for growth the vegetative parts emerge very slowly, and the blossoming period alone may extend over more than six weeks. Usually the greater part of the crop develops from this spring bloom.

The second flush comes out very rapidly, usually during the hot dry weather of May several weeks in advance of the rainy season, and in a few days the leaves reach a width of an inch or more. This flush is much less evenly distributed over the tree and is rather irregular in beginning growth. There occurs at this time or somewhat later a small quantity of bloom from which develops the June bloom fruit, which is quite inferior in quality. The so-called "June bloom" is relatively insignificant in quantity. It occurs practically only on trees with little or no fruit resulting from the spring bloom, or following a drought, or on trees which have some root or trunk disease.

The third flush usually starts growing in September, well after the rainy season has passed. The quantity and character of growth is essentially the same as that occurring in May, but seldom accompanied by blossoms. Between these main flushes an occasional but irregular putting out of vegetative parts is observed.

In young groves which have not come into bearing the vegetative growth is quite comparable with that occurring in bearing trees, the chief difference being in the number of flushes. Vigorous young trees which are being forced by fertilizers and cultivation are likely to put on five or six distinct flushes during the first year after setting, these decreasing in number until the tree begins bearing a fair crop of fruit. After that time there are usually only three main flushes during the year.

Nursery trees, both budded and seedlings, are continually sending out successive vegetative growths from early spring until late fall, frequently making an extension of as much as 60 inches during the year. Rough lemons especially have emerging leaves present practically throughout the entire growing season, while the sour orange is inclined to be more regular in its growths, the more vigorous plants putting on about 10 flushes.

DISEASE AS INFLUENCED BY THE STOCK.

There is a widespread popular impression that grapefruit growing on rough-lemon roots is more susceptible to scab than when the same variety is grown on sour-orange or grapefruit stock under the same environmental conditions—that the stock lessens the resistance of the scion to this disease.

In general, scions on rough-lemon stock produce a much greater vegetative growth during the first few years than is the case with other popular root systems. Such being the case, trees on these roots have many more leaves and perhaps a greater number of fruits passing through the stages of growth susceptible to infection. Under these actual conditions there is a considerable increase in the chances for trees on rough-lemon roots to become infected even where resistance remains constant. If the stock exerts an appreciable influence on the inherent susceptibility to scab it should show up at least occasionally in inoculation experiments.

A critical study of the results from inoculation experiments conducted during the past five years, coupled with the summary of general orchard observations made over the same period, indicate that there is no material difference in percentage or degree of infection that could reasonably be attributed to immunizing or sensitizing influences produced by the stock on the scion.

ADAPTATION OF THE FUNGUS.

That citrus scab will eventually be as serious on the round orange as it now is on grapefruit is the belief of a large number of practical horticulturists and a few pathologists (*23*). This opinion is based on the widespread impression that for a number of years this disease was confined to the sour orange and rough lemon, later "adapted" itself to grapefruit, and still later to the round orange. This alleged adaptation on the part of the scab fungus has been explained in several ways. Some claim the grapefruit and round orange, as a result of cultural practices, are rapidly losing their original immunity; others are of the opinion that the scab fungus is gradually adapting itself to the more resistant species; still others would explain the condition on the ground that very virulent strains of the causal organism capable of infecting grapefruit and orange have resulted as natural mutations; and a few do no more than make the prediction that within a short time the orange will be as seriously affected as is now the case with grapefruit.

In the case of citrus scab there appears to be no sound basis for such claims in spite of the fact that such a phenomenon has been noted for other pathogens. Within a few years after citrus scab was first recorded in America, Underwood (*30*) reported the commercial species as being susceptible to infection in essentially the same proportion as is the case to-day. His report was made before the grapefruit as a fruit, or rough lemon as a root stock, began to attract very much attention from commercial growers. Since then these species have gained a great deal of popularity, resulting in the setting out of millions of trees susceptible to infection from scab. This has increased immeasurably the number of foci of infection and also the mathematical chance for infection of all species.

If the scab fungus is adapting itself to the more resistant species, this transition is going on very slowly, so much so that it can not be measured even when viewed over a period of 30 years. The causal organism isolated from round orange, grapefruit, and avocado has shown itself by actual inoculation tests to be neither more nor less pathogenic to grapefruit than was the same organism isolated from sour orange and grapefruit. Cultural studies of the causal organism isolated from various hosts also failed to reveal any difference in the fungus, and field studies over a period of five years fail to give the slightest indication that the round orange is losing its original resistance. There is no valid reason for presuming that at least within the life of trees now planted the orange will be as susceptible to infection as is grapefruit at present. There is no evidence that an inherently more virulent strain of the scab fungus is developing.

INOCULATION EXPERIMENTS.

In order to determine accurately the period of development during which fruit and foliage are likely to become infected and the relative susceptibilities of some citrus species to scab, a rather extensive series of inoculation experiments was conducted on young citrus trees growing on the laboratory grounds at Orlando, Fla., and in a near-by bearing grapefruit grove. In addition, a limited number of tests were made in bearing groves at other points.

The inoculum used in these experiments was from pure cultures of the scab fungus isolated from the several highly susceptible citrus species, from the resistant sweet orange, and from the avocado, as well as from cultures received from Porto Rico. More complete data relative to the source of cultures are given in Table 5.

TABLE 5.—*Sources of cultures of the citrus-scab fungus used in inoculation tests.*

Host.	Part.	Isolated by—	Date.	From—
Grapefruit	Leaf	J. A. Stevenson	1917	Porto Rico.
Rough lemon	do	H. E. Stevens	1916	Florida Experiment Station.
Rough lemon (?)	(?)	(?)	(?)	H. S. Fawcett.
Grapefruit	Leaf	Fruit-disease investigations.	1916	Orlando, Fla.
Do	Old fallen leaf	do	Jan. 5, 1917	Do.
Do	do	do	Feb. 15, 1917	Do.
Do	do	do	do	Do.
Do	Dried fallen leaves.	do	do	Do.
Do	Fruit	do	May 20, 1917	Do.
Do	do	do	March, 1919	Winter Park, Fla.
Sour orange	Leaf	do	December, 1918	Orlando, Fla.
Do	Fruit	do	April, 1919	Do.
Sweet orange (Ruby Blood).	Leaf	do	December, 1916	Tavares, Fla.
Sweet orange (Pineapple).	do	do	January, 1917	Orlando, Fla.
Satsuma orange	Fruit	do	July, 1916	Thomasville, Ga.
King orange	Leaf	do	February, 1917	Winter Garden, Fla.
Tangerine	do	do	April, 1917	Do.
Tangelo	do	do	March, 1919	Orlando, Fla.
Calamondin	do	do	March, 1920	Do.
Sweet bittersweet	do	do	November, 1919	Do.
Sour Rangpur	do	do	do	Do.
Avocado	do	do	April, 1918	Homestead, Fla.

In general the cultures were grown on potato-dextrose agar for about three weeks before being used as inoculum. A liberal quantity of the vegetative fungus was placed on wet absorbent cotton wads (Pl. XV, Fig. 2). These plasters were so placed that the fungus was in contact with the part to be infected, and they were then covered with several layers of paraffin paper (Pl. XVI), except that in special cases the plasters were left in contact with the parts to be infected for at least 24 hours. Frequently in cool weather the plasters were on 48 hours. At the expiration of this time the paper and moist cotton plasters were removed, and the inoculated parts left unprotected. During the progress of the work, control tests were made by similar methods, except that the inoculum was not used.

Lesions resulting from artificial infections (Pl. I, Fig. 3) developed in from 5 to 10 days after the inoculation was made, but in every case final observations were deferred 15 days or more after the plasters were removed.

Table 6 gives the results of artifical inoculations of fruits of grapefruit, Satsuma orange, and Dancy tangerine with the citrus-scab fungus, and Table 7 gives similar results on leaves of a number of susceptible species. Numerous inoculations were attempted on sweet oranges, but without exception they gave negative results. Because of space limitation these tests are not here reported in detail.

TABLE 6.—*Results of inoculations with the scab fungus on grapefruit, Satsuma orange, and Dancy tangerine fruits.*

Date.	Size of fruit (in sixteenths of an inch).	Total inoculations.	Dropped or lost.	Fruits remaining.	Total positive.	Total negative.	Percentage positive.	Degrees of infection.
Grapefruit:								
Apr. 17, 1917	4	6	0	6	6	0	100	Very severe.
Apr. 10, 1920	4	58	9	49	48	1	98	Do.
Do	4 to 5	31	6	25	23	2	92	Do.
Apr. 19, 1920	4 to 8	230	65	165	129	36	78	Do.
Do	4 to 8	46	9	37	4	33	10.8	33 Royal, no scab; 4 Foster, badly scabbed.
Apr. 20, 1917	4 to 12	16	6	10	5	5	50	Very severe on small fruits.
May 2, 1917	2 to 20	20	1	19	11	8	58	Infection mostly on smallest fruits.
May 9, 1917	4 to 20	16	2	14	11	3	79	Do.
Apr. 23, 1920	5	50	20	30	29	1	97	Moderate.
May 27, 1920	6 to 8	36	22	14	13	1	93	Severe.
Apr. 3, 1919	6	102	49	53	53	0	100	Do.
Apr. 20, 1918	6 to 8	38	9	29	23	6	79	Severe on smallest; moderate on larger fruits.
Apr. 10, 1919	6 to 8	100	33	67	67	0	100	Moderate.
May 27, 1920	6 to 8	36	22	14	13	1	93	Do.
Apr. 27, 1920	6 to 8	36	22	14	13	1	93	Do.
June 4, 1920	6 to 12	40	1	39	9	30	23	Lesions on smaller fruit only.
June 11, 1920	4 to 12	25	6	19	2	17	10.5	Yellow, poor specimens.
May 1, 1917	8	25	2	23	17	6	74	Only a few lesions on each fruit.
May 13, 1920	8	24	5	19	19	0	100	Very severe; Hall (*Silver Cluster*).
Apr. 17, 1919	8 to 10	108	32	76	34	42	45	Infection on smallest fruits only.
Apr. 15, 1918	8	30	10	20	15	5	75	Moderate.
June 17, 1920	14 to 16	15	5	10	0	10	0	
Do	10 to 24	50	20	30	0	30	0	
Apr. 24, 1919	11 to 14	100	29	71	0	71	0	
May 1, 1919	11 to 17	99	41	58	0	58	0	
Apr. 29, 1920	12	48	19	29	6	23	21	One or two small spots on each fruit; Hall variety.
June 11, 1920	12	21	5	16	0	16	0	
May 13, 1920	12	14	6	8	1	7	12.5	Lesions very small; only one or two per fruit.
May 8, 1920	15 to 18	50	15	35	0	35	0	
May 13, 1920	16	12	6	6	0	6	0	
May 8, 9, 1919	1 to 22	100	32	68	0	68	0	
May 13, 1920	1 to 18	7	1	6	0	6	0	
May 15, 1919	1 to 24	100	9	91	0	91	0	
Satsuma orange:								
May 24, 1917	4 to 8	328	157	171	147	24	86	Very severe.
May 8, 1920	5	17	3	14	14	0	100	Severe.
May 31, 1917	10 to 20	100	50	50	3	47	6	Moderate on smallest fruits.
June 4, 1920	6 to 8	18	10	8	7	1	88	Severe.
May 27, 1920	8	5	1	4	4	0	100	Do.
June 11, 1920	8	5	2	3	0	3	0	
Do	8	4	3	1	0	1	0	
June 25, 1920	12	10	2	8	0	8	0	
June 17, 1920	14	10	6	4	0	4	0	
June 25, 1920	16	10	1	9	0	9	0	
Dancy tangerine:								
June 4, 1920	4	24	7	17	13	4	76	Very severe.
June 11, 1920	6	20	15	5	5	0	100	Do.
June 17, 1920	6	25	14	11	11	0	100	Do.
June 25, 1920	6	10	2	8	8	0	100	Do.
Do	6 to 8	10	0	10	9	1	90	Do.

TABLE 7.—*Results of inoculations with the scab fungus on expanding leaves of grapefruit, King and Satsuma oranges, tangerine, lemon, and tangelo.*

Date.	Size, width of leaves (in sixteenths of an inch).	Total inoculations.	Dropped.	Leaves remaining.	Total positive.	Total negative.	Percentage, positive.	Degree of infection.
Grapefruit:								
May 1, 1917	(1)	50	9	41	28	13	68	Very severe.
May 21, 1917	(1)	40	5	35	26	9	74	Do.
Feb. 3, 1919	(1)	16	0	16	16	0	100	Do.
Feb. 19, 1919	(1)	4	3	1	0	1	0	
Feb. 20, 1919	(1)	5	0	5	5	0	100	Do.
Do	(1)	5	4	1	1	0	100	Do.
Do	(1)	4	1	3	3	0	100	Do.
Feb. 28, 1919	(1)	11	0	11	8	3	73	Very severe; 16 hours exposure.
Mar. 3, 1919	(1)	15	2	13	10	3	77	Very severe; 4 hours exposure.
Do	(1)	8	4	4	3	1	75	Very severe; 11 hours exposure.
Do	(1)	7	3	4	3	1	75	Very severe; 6 hours exposure.
Apr. 18, 1919	(1)	10	0	10	0	10	0	Royal grapefruit.
Apr. 22, 1919	(1)	20	4	16	8	8	50	Severe.
Apr. 29, 1919	(1)	13	0	13	13	0	100	Do.
Do	(1)	7	1	6	5	1	84	Do.
Do	(1)	18	2	16	0	16	0	Royal grapefruit.
Apr. 2, 1920	(1)	36	5	31	23	8	74	Severe.
Apr. 5, 1920	(1)	36	5	31	23	8	74	Do.
Apr. 6, 1920	(1)	20	1	19	15	4	79	Do.
Mar. 8, 1919	4 to 64	12	3	9	3	6	33	16 hours exposure.
Mar. 12, 9919	6 to 20	15	0	15	0	15	0	
Mar. 13, 1919	8 to 16	14	0	14	0	14	0	
Apr. 14, 1920	8	39	0	39	0	39	0	
Apr. 10, 1920	8 to 16	23	0	23	0	23	0	
Mar. 8, 1919	8 to 48	9	5	4	0	4	0	Do.
Apr. 10, 1920	8 to 16	20	0	20	0	20	0	Royal grapefruit.
Mar. 12, 1919	8 to 20	10	0	10	0	10	0	
Apr. 16, 1920	12	32	0	32	0	32	0	
King orange:								
Feb. 28, 1920	(1)	10	0	10	9	1	90	Severe.
Apr. 5, 1920	(1)	50	0	50	10	40	20	Moderate.
pr. 20, 1920	4 to 8	61	7	54	0	54	0	
Apr. 16, 1920	8	50	10	40	0	40	0	
Satsuma orange:								
Mar. 26, 1919	(1)	30	4	26	21	5	81	Do.
Mar. 12, 1919	(1)	9	0	9	7	2	78	Do.
Mar. 19, 1919	8	20	5	15	0	15	0	
Mar. 13, 1919	8	4	0	4	0	4	0	
Mar. 12, 1919	8 to 24	8	0	8	0	8	0	
Tangerine:								
Mar. 3, 1919	(1)	5	1	4	4	0	100	Do.
Apr. 10, 1920	8	14	0	14	0	14	0	
Mar. 12, 1919	8 to 16	16	0	16	0	16	0	
Lemon:								
Feb. 19, 1919	(1)	12	4	8	8	0	100	Very severe.
Do	(1)	7	3	4	4	0	100	Do.
Feb. 28, 1919	(1)	4	0	4	4	0	100	16 hours exposure.
Mar. 1, 1919	(1)	4	0	4	4	0	100	Very severe.
Do	(1)	2	0	2	2	0	100	Severe.
Mar. 3, 1920	(1)	2	0	2	2	0	100	Do.
Do	(1)	3	2	1	1	0	100	Do.
Apr. 5, 1920	(1)	5	0	5	4	1	80	Moderate.
Apr. 10, 1920	4 to 8	17	2	15	1	14	7	Very slight.
Apr. 15, 1920	8 to 12	24	4	20	0	20	0	
Mar. 12, 1920	8 to 16	12	0	12	0	12	0	
Mar. 20, 1920	12	20	2	18	0	18	0	
Tangelo:								
Jan. 31, 1919	(1)	4	2	2	2	0	100	Very severe.
Mar. 3, 1919	(1)	25	5	20	20	0	100	Do.
Feb. 28, 1919	(1)	10	0	10	10	0	100	Do.
Feb. 3, 1919	(1)	16	0	16	16	0	100	Do.
June 2, 1920	(1)	20	5	15	12	3	80	Moderate.
June 7, 1920	4 to 8	25	2	23	0	23	0	
Mar. 12, 1919	6 to 16	15	0	15	0	15	0	
Apr. 10, 1920	8 to 16	19	0	19	0	19	0	
Apr. 16, 1920	12	30	4	26	0	26	0	

[1] Expanding.

These inoculation experiments were conducted on properties where more or less citrus scab occurs normally, consequently a small proportion of scab developed in the water checks, but not enough to invalidate the general conclusions from these experiments.

Inoculum from various strains of the citrus-scab fungus was used on each host plant listed. There is no evidence that any one strain of the scab fungus is more virulent than another.

The smallest sizes of citrus fruits in Table 8 represent stages immediately after the falling of the petals. The evidence is that susceptibility is highest at this time and decreases progressively until a diameter of about three-fourths of an inch is reached for grapefruit when they attain immunity.

The leaves of all species tested are found to be most susceptible to infection as they emerge from the bud. They become progressively resistant and reach a stage of immunity when they have developed to one-half inch in width (Pl. VIII, Fig. 2).

The Royal grapefruit, both leaves and fruits, appears to be immune to scab infection.

The scab fungus after growing on artificial media four years is as pathogenic as recently isolated strains.

TABLE 8.—*Water-blank checks on grapefruit, Satsuma orange, and tangerine fruits.*

Date.	Size of fruit (in sixteenths of an inch).	Total inoculations.	Dropped or lost.	Fruits remaining.	Total positive.	Total negative.	Percentage positive.	Degree of infection.
Grapefruit:								
Apr. 10, 1920	4 to 5	19	4	15	4	11	26	Moderate.
Apr. 23, 1920	5	20	7	13	1	12	8	Do.
May 2, 1917	2 to 20	5	0	5	0	5	0	
Apr. 3, 1919	6	40	28	12	3	9	25	Do.
Apr. 10, 1919	6 to 8	40	20	20	0	20	0	
Apr. 20, 1918	6 to 8	20	6	14	2	12	14	Slight.
Apr. 15, 1918	8	25	9	16	2	14	12.5	Do.
May 13, 1920	8	25	5	20	1	19	5	Moderate.
Apr. 17, 1919	8 to 10	40	9	31	4	27	12.9	Slight.
Apr. 19, 1919	8 to 12	39	10	29	0	29	0	Many yellow.
May 9, 1917	8 to 16	30	5	25	4	21	16	Moderate.
June 11, 1920	10 to 24	25	6	19	0	19	0	
Apr. 25, 1919	11 to 14	40	9	31	2	29	6.4	Slight, probably not scab.
May 8, 1920	12 to 16	47	10	37	0	37	0	
May 1, 1919	15	40	11	29	3	26	10.3	Do.
May 8, 1919	17	40	12	28	1	27	3.5	Do.
Apr. 30, 1919	16 to 20	48	20	28	0	28	0	
May 15, 1919	28	40	4	36	0	36	0	
Satsuma orange:								
May 24, 1917	4 to 8	36	11	25	5	20	20	Moderate
June 4, 1920	6 to 8	10	1	9	0	9	0	
May 24, 1917	6 to 8	36	11	25	5	20	20	Slight.
May 17, 1920	8	43	12	31	4	27	13	Do
May 31, 1917	10 to 20	25	18	7	1	6	14	Do.
Tangerine:								
June 4, 1920	4	5	2	3	1	2	33	Moderate.

To determine whether or not *Cladosporium citri* Massee usually found in older scab scars was responsible for the disease, a set of tests parallel with those in Tables 6 and 7 was run. The organisms used in this test were isolated from scab lesions from time to time, grown and applied in a manner similar to that employed in the preceding inoculation tests. The data from these tests, as indicated in Table 9 resulted from inoculations on fruit and leaves of the Satsuma orange and grapefruit.

TABLE 9.—*Results of inoculations of Cladosporium citri on leaves and fruits of grapefruit and Satsuma orange.*

Date.	Part.	Size (in sixteenths of an inch).	Total inoculations.	Dropped.	Remaining.	Total positive.	Total negative.	Percentage positive.	Degree of infection.
Grapefruit:									
Oct. 24, 1917	Leaves	([1])	37	13	24	0	24	0	
Apr. 5, 1918	...do..	([1])	50	26	24	1	23	4	Slight.
May 1, 1918	...do..	([1])	51	29	22	2	20	9	Do.
May 2, 1917	Fruit .	4 to 8	50	23	27	2	25	7.4	Do.
Apr. 10, 1918	...do..	6 to 8	40	12	28	2	26	7	Do.
Apr. 22, 1920	...do..	5	48	12	36	3	33	8.3	Do.
May 9, 1917	...do..	8 to 16	46	10	36	5	31	14	Do.
May 16, 1917	...do..	8 to 24	50	12	38	5	33	13	Do.
Apr. 19, 1919	...do..	12	40	16	24	1	23	4	Do.
May 8, 1920	...do..	12 to 16	50	9	41	0	41	0	
Apr. 30, 1919	...do..	16 to 20	42	7	35	0	35	0	
Satsuma orange:									
May 24, 1917	...do..	4 to 8	52	20	32	3	29	9.3	Do.
June 17, 1920	...do..	8	50	23	27	3	24	11	Do.
June 28, 1920	...do..	12	51	19	32	0	32	0	

[1] Expanding.

It is evident from Table 9 that the Cladosporium found in citrus-scab lesions is not responsible for the disease. The checks in the main show a slightly higher percentage of scab than do the inoculations with Cladosporium organism but not higher than the checks shown in Table 6 for the series of inoculations with the citrus-scab organism.

SPRAYING EXPERIMENTS.

Until recently very little spraying was done in Florida, even on an experimental basis. Growers generally were not inclined to use copper sprays, because such fungicides, while effective against scab, also kill off the entomogenous fungi, resulting in a greatly increased number of insect pests. Unless extra applications of insecticides are made following applications of Bordeaux mixture, the damage resulting from serious scale infection is likely to more than offset the benefits derived from scab control. On the other hand, growers who used lime-sulphur solution claim this material is only partially effective against scab but even then is more desirable for citrus orchard use than Bordeaux mixture.

Similar results were obtained in experimental spraying by Stevenson in Porto Rico (*25, 26*) and Grossenbacher (*7*), as well as by Florida fruit growers who applied the two materials for test purposes.

The spraying experiments of the writer were interrupted by the freeze of February, 1917, and later by circumstances resulting in part at least from war conditions. During several seasons no scab developed in the orchards where spraying experiments were conducted. Nevertheless, a great many careful studies made of spray schedules employed in commercial groves in Florida and Alabama where scab was successfully controlled, together with the results of inoculation tests and of definite orchard spraying experiments, and of demonstrations, lead the writer to feel confident that the above-mentioned general conclusions are correct and that the disease can be controlled satisfactorily and economically. Good judgment must be used in selecting and applying the fungicide and in following it with insecticides if necessary.

In addition to these field studies and observations, critical spraying experiments were conducted in a nursery of sour-orange and rough-lemon seedlings at Orlando, Fla., during 1919 and 1920. This nursery was set out in the spring of 1918 and was not sprayed that year, resulting in a very general infection on leaves and twigs to serve as sources of early infection the following year.

During the progress of this spraying experiment for citrus-scab control in the nursery the following materials were used:

Formula 1: Bordeaux mixture, 3–3–50, prepared in the usual way.

Formula 2: Bordeaux mixture, 3–3–50, plus 0.5 per cent oil in emulsified form. The Bordeaux mixture was prepared in the usual manner to which sufficient oil emulsion was added to make 0.5 per cent oil in solution.

Formula 3: Bordeaux mixture, 2–2–50, plus 0.5 per cent oil in emulsified form. Prepared in same manner as formula 2.

Formula 4: Bordeaux mixture, 1–1–50, plus 0.5 per cent oil in emulsified form. Prepared in same manner as formula 2.

Formula 5: Commercial Bordeaux paste (6 per cent metallic copper), 12¾ pounds in 50 gallons of water, the equivalent of 3–3–50, plus 0.5 per cent oil in emulsified form.

Formula 6: Homemade Bordeaux paste, in proportions to equal 3–3–50 Bordeaux mixture, plus 0.5 per cent oil in emulsified form.

Formula 7: Burgundy mixture, 3–3½–50, prepared in the usual manner.

Formula 8: Copper soap (Pritchard and Clark's (*16*) formula). Prepared by adding 3 pounds of dissolved resin-fishoil soap to one-half pound bluestone dissolved in 50 gallons of water.

Formula 9: Lime-sulphur solution, 32° B. diluted 1 to 40.

Formula 10: Lime-sulphur solution, 32° B. diluted 1 to 40 plus stabilized oil emulsion, 0.5 per cent.

The oil emulsion used in these spray materials was prepared according to Yothers (*32*, p. 19) by emulsifying 2 gallons of mineral oil with 2 pounds (1 quart) of fishoil soap and 1 gallon of water. To dilute 3 quarts of this emulsion to 50 gallons gives a proportion of 1 per cent oil.

In 1919 the sprays were applied at weekly intervals, beginning in March and continuing throughout the growing season. The applications were made with a power outfit developing about 300 pounds pressure, and as a rule the sprays were applied with great thoroughness.

The following year the first applications were delayed until a reasonable amount of infection had taken place throughout the nursery, and were made at intervals of 14 days. The same power outfit, pressure, etc., were employed, and the spraying was done as thoroughly as could be expected under commercial conditions. Table 10 shows the results of spraying experiments for the control of citrus scab in a sour-orange and rough-lemon nursery at Orlando, Fla., during 1919 and 1920.

TABLE 10.—*Scab control in the citrus nursery in 1919 and 1920.*

Formula.	Year.	Spray materials used.	Spray injury on foliage or twigs.	Control of scab.
No. 1	1919	Plain Bordeaux mixture, 3-3-50	None	Absolute.
No. 2	1919	Bordeaux mixture, 3-3-50, plus 0.5 per cent oil as emulsion.	do	Do.
No. 7	1919	Burgundy mixture	Russeting of leaves moderate.	Do.
No. 9	1919	Lime-sulphur solution	Defoliation serious.	Moderate, about 50 per cent.
No. 10	1919	Lime-sulphur solution plus 0.5 per cent oil as emulsion.	do	Do.
No. 1	1920	Plain Bordeaux mixture, 3-3-50	None	Absolute.
No. 2	1920	Bordeaux mixture, 3-3-50, plus 0.5 per cent oil as emulsion.	do	Do.
No. 3	1920	Bordeaux mixture, 2-2-50, plus 0.5 per cent oil as emulsion.	do	Do.
No. 4	1920	Bordeaux mixture, 1-1-50, plus 0.5 per cent oil emulsion.	do	Do.
No. 5	1920	Commercial Bordeaux paste plus 0.5 per cent oil as emulsion.	do	Do.
No. 6	1920	Homemade Bordeaux paste	do	Do.
No. 8	1920	Copper soap	do	Do.
Check	1919			Very severe infection, 90 per cent.
Check	1920			Serious infection, somewhat less than 1919, 72 per cent.

At the end of each year 1,000 or more leaves were selected at random and counted for each plat and the presence or absence of citrus scab recorded.

The beneficial results associated with citrus-scab control were very evident during the progress of the work. It was especially noticeable during the spring and early summer of 1919. On June 30, 1919, measurements of growth in height were made over the various plats. At that time and throughout the rainy season of June and July the stunting effect of citrus scab was conspicuous. When the rains stopped and dry weather set in, thereby largely preventing citrus-scab infection, the check plat made a surprisingly rapid growth until checked by cold weather.

The following year citrus scab did not become at all serious until the rainy season set in, and for that reason the stunting effect was not particularly marked.

No spray injury was noted until hot weather set in, then considerable scorching of mature leaves and blighting of tender shoots was usually experienced on plats sprayed with lime-sulphur solution. Defoliation was very serious with the sour orange, but not quite so marked in the case of the rough lemon. Oil emulsion added to the lime-sulphur solution increased the injury by about 20 per cent. Neither material (formulas 9 and 10) gave more than 50 per cent control.

Burgundy mixture (formula 7) produced a slight russeting of foliage, but not in sufficient proportions to be considered serious. Nevertheless, with a slight excess of either the sal soda or the bluestone, considerable damage is likely to occur, and for that reason it appears to be too treacherous to be employed in ordinary nursery work where unskilled labor has to be relied upon to attend to the preparation and application of the sprays. This material gave perfect control of scab.

Copper soap (formula 8) gave very pleasing results. No injury was found on the trees sprayed with this material. This formula carries an excess of soap and apparently is quite safe for use. It controlled scab perfectly.

Plain Bordeaux mixture (formula 1) controlled scab perfectly, and no spray injury resulted. The chief objection to copper sprays, especially Bordeaux or Burgundy mixtures, is that scale insects usually become very numerous following such applications unless drastic measures are taken to prevent these insects from multiplying.

Bordeaux mixture plus oil emulsion (formulas 2, 3, 4, 5, and 6) evolved especially to overcome the objectionable aftereffects of plain Bordeaux mixture, also controlled scab perfectly. It adheres as well as plain Bordeaux mixture and spreads much better. The weaker formulas of Bordeaux mixture gave equally as good results as the stronger materials. Where this combination spray was applied, scale insects were held down satisfactorily without extra sprayings. No injury resulted from the use of any of these formulas.

COMMERCIAL CONTROL.

While the actual control of citrus scab per se by means of sprays is not especially difficult if the spraying is done with thoroughness, at the proper time, and with effective materials, the commercial control of scab on grapefruit presents numerous factors for consideration, some of which are extremely important.

Perhaps the most important single factor, in so far as the well-being of the tree is concerned, is the beneficial or entomogenous fungi. So effective are these fungi in the control of certain insect pests that there are numerous orchards which bear plentiful crops of excellent fruit without the aid of sprays. About 12 species of entomogenous fungi are recognized in Florida citrus orchards. The earliest forms begin growth about the 1st of May, and the later forms are active until late fall or winter.

It is true that the time for spraying against scab on grapefruit usually has passed before the entomogenous fungi become active. It is also true that any fungicide especially effective in scab control is likely to persist on the sprayed parts for a considerable time after the period of scab infection has passed. Further, any fungicide effective against scab is likely to be very harmful to the entomogenous fungi. Therefore when an effective, lasting spray is applied to control the scab fungus a corresponding control of entomogenous fungi is most likely to occur, and this would result in an enormous increase of insect pests unless drastic measures are taken to check them.

These entomogenous fungi seem to thrive best under local conditions which are especially favorable for citrus scab. For example, in those rather moist localities where natural control of insect pests is most pronounced attacks from citrus scab are usually severe.

Citrus scab tends to vary greatly from year to year and section to section. Even in a given locality it varies a great deal, and the fact that an orchard is affected seriously with citrus scab is by no means strong evidence that the same property will be even lightly affected the following year.

Nevertheless, there are localities where citrus scab is regularly serious, others where the disease is usually moderately prevalent, and still others which are attacked only during years especially favorable for citrus-scab development. For the sake of economy these three types of localities should not have the same spray schedule for the control of citrus scab. A spray program which would list the least number of applications necessary to produce clean fruit in localities where citrus scab is constantly serious would be unnecessarily expensive in time consumed and materials used where the disease occurs only during years especially favorable for scab development.

On the other hand, one or two applications of lime-sulphur solution, though it is a weak, short-lived fungicide, made during the scab season is money well invested, even if scab does not occur, for the reason that such applications practically eliminate red spiders and greatly reduce rust-mite injury.

The judicious selection of the spray material for use in a citrus orchard is by no means an easy task, because all are not equally effective against scab, and certain of them are likely to be followed by injurious or even disastrous effects from later insect attack. Bordeaux mixture is the most effective spray against scab, and when made up with lake or shallow well (soft) water spray injury seldom follows. Usually deep well (hard) water is satisfactory, but a few instances are on record where a moderate amount of spray burn has resulted from Bordeaux mixture being made up with such water and applied on citrus trees. In certain localities hard water can be used with safety, while in others it is likely to be followed by more or less spray burn. Unless extra applications of insecticides are made, scale insects are very likely to increase rapidly and do great damage following this spray. Commercial Bordeaux preparations (Wallace, *31*) when used in sufficient quantities to give about three-sixteenths of 1 per cent copper in the diluted spray are effective though expensive substitutes for homemade Bordeaux mixture. Bordeaux mixture plus oil emulsion is equally as effective against citrus scab as is plain Bordeaux mixture and against insects as is the same strength of oil emulsion when applied separately. The fungicidal effects outlast the insecticidal effect, and for this reason the usual treatment and sometimes extra applications for scale are required following the use of Bordeaux mixture plus oil emulsion. Burgundy mixture is quite effective against citrus scab, but if not carefully made is likely to cause some injury to fruit or foliage. This spray is considered too risky for general use. Scale insects become very numerous following applications of this material. Ammonical copper carbonate solution is much less effective against citrus scab than is Bordeaux mixture. In general, it is not a desirable spray for scab control. Scale insects increase considerably following its use. Lime-sulphur solution, 32° B., diluted 1 to 40, is not more than 50 per cent effective against severe scab infection, but for certain reasons it can be applied profitably in many orchards. No spray injury has been observed where this material was used during the spring for scab control. This spray kills red spiders, rust mites, and scale crawlers. Dry lime-sulphur and barium sulphur when used on the basis of sulphur equivalents of standard lime-sulphur solution, seem to be fairly satisfactory but quite expensive substitutes for the commercial lime-sulphur solution. Soda-sulphur or sodium-sulphur compounds are expensive and comparatively ineffective substitutes for lime-sulphur solution for use against scab. The hazard of spray burn is especially great following the use of sodium-sulphur compounds of fungicidal strengths.

Dusting for the control of citrus scab has not been tested thoroughly. There seems to be no good reason for assuming that dusting with materials now used will prove as effective or as practical as spraying.

TABLE 11.—*Spray schedules for the control of citrus scab in Florida.*

No. 1.—FOR ORCHARDS WHERE CITRUS SCAB IS ALWAYS SERIOUS.[1]

Application.	Time of application.	Materials used.	Object and remarks.
First	Just before growth sets in.	Bordeaux mixture, 3-3-50, plus 1 per cent oil as emulsion.[2]	To cover old scab lesions. Direct the spray especially toward the under surface of the leaves; reduces very early citrus-scab infection.
Second	In height of bloom	Bordeaux mixture, 3-3-50, plus 0.5 per cent oil as emulsion.[2]	For the protection of expanding leaves and small fruit against scab and melanose.
Third	Two weeks later	do	For the protection of small fruit against scab and melanose.
Fourth	Two weeks after third application.	Bordeaux mixture, 3-3-50, plus 1 per cent oil as emulsion.	Advisable if the season is rainy. For protection against scab; will also reduce early melanose infection.

CAUTION: Insecticidal applications must follow to prevent serious scale injury.

No. 2.—FOR ORCHARDS WHERE CITRUS SCAB VARIES FROM MODERATE TO SERIOUS.[3]

Application.	Time of application.	Materials used.	Object and remarks.
First	Just before growth sets in.	Bordeaux mixture, 3-3-50, plus 1 per cent oil as emulsion.	To cover old scab lesions. Direct the spray especially toward the under surface of the leaves; reduces very early citrus-scab infection.
Second	In height of bloom	Lime-sulphur solution, 1 to 40, or Bordeaux mixture, 3-3-50, plus 0.5 per cent oil as emulsion.	To protect expanding leaves and small fruit from scab and melanose.[4] If the season is normal use lime-sulphur; if the season is rainy use Bordeaux mixture.
Third	Two weeks later	do	To protect small fruit from scab and melanose. If the season is normal use lime-sulphur; if the season is rainy use Bordeaux mixture.
Fourth	Two weeks after third application.	Bordeaux mixture, 3-3-50, plus 1 per cent oil as emulsion.	If the season is rainy, probably advisable for protection of smallest fruits against scab; will also reduce early melanose infection.

No. 3.—FOR ORCHARDS WHERE CITRUS SCAB IS OF MINOR IMPORTANCE.[5]

Application.	Time of application.	Materials used.	Object and remarks.
First	Just before growth sets in.	Lime-sulphur solution, 1 to 30.	To cover the old scab lesions. Direct the spray especially toward the under surface of the leaves; prevents early scab infections.
Second	In height of bloom	Lime-sulphur solution, 1 to 40.	To prevent infections on expanding leaves and small fruit.
Third	Two weeks later	do	To prevent infections on expanding leaves and small fruit. Advisable only when the season is especially favorable for scab development.

[1] To insure bright clean fruit at harvest time follow schedule No. 1 with the regular scale, white-fly, and rust-mite spray applications (see Farmers' Bulletin 933), one or two additional applications of which should be used to check the heavy increase of insect pests following copper sprays.

[2] Prepare 3-3-50 Bordeaux mixture in the usual way. Three quarts of oil emulsion, Government formula, in 50 gallons of Bordeaux mixture gives 1 per cent oil. *Add the oil emulsion to the Bordeaux mixture while the latter is being thoroughly agitated in the spray tank.* Keep up the agitation while spraying.

Preparation of boiled-oil emulsion, Government formula.

[See U. S. Dept. Agr., Farmers' Bulletin 933.]

Paraffin oil	gallons	2
Water	gallon	1
Fishoil soap	pounds	2

Put oil, water, and soap into a kettle or other vessel that will stand fire and heat to the boiling point. While still very hot, but after removal from the fire, pump the material into another vessel with a bucket pump and then pump back again.

[3] To insure clean, bright fruit at harvest time follow schedule No. 2 with regular scale, white-fly, and rust-mite spray applications. When Bordeaux mixture is used additional applications of oil emulsion most likely will be necessary.

[4] Lime-sulphur solution has not proved effective in melanose control.

[5] To insure clean, bright fruit at harvest time follow schedule No. 3 with the regular scale, white-fly, and rust-mite spray applications.

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The spray schedules shown in Table 11 are drawn to meet the varying degrees of citrus-scab outbreaks as they occur in Florida orchards. Spray schedule No. 1 should be followed where scab is usually present in serious proportions; spray schedule No. 2 should be followed in localities where citrus scab varies in prevalence from serious to moderate; spray schedule No. 3 should be followed in localities where citrus scab is a minor disease. Because of its effect upon spiders, mites, and insects, schedule No. 3 will prove profitable even if citrus scab does not occur on unsprayed trees.

Nurseries can be kept commercially free from citrus scab by occasional applications of Bordeaux mixture plus oil emulsion. On an average, monthly applications probably will afford adequate protection. In many instances a smaller number of applications will suffice; however, the frequency of applications is dependent upon local and seasonal conditions. Care must be taken to keep new flushes protected during periods of wet weather.

The use of Bordeaux mixture plus oil emulsion was followed by a considerable increase in the growth of grapefruit seedlings even when citrus scab did not occur in the planting. Where citrus scab has occurred on sour-orange and rough-lemon seedlings the increase of growth following applications of Bordeaux mixture plus oil emulsion has been greater than the probable retardation due to scab. These two observations seem to indicate that this spray mixture may act as a growth stimulus in citrus nurseries.

SUMMARY.

Citrus scab, an important disease of foreign introduction, attacks many citrus species. It occurs in India, China, Formosa, Japan, Hawaii, Paraguay, Brazil, Canal Zone, Yucatan, West Indies, Canary Islands, South Africa, and the citrus-growing regions of the Gulf States. As yet it has not become established in California or Arizona.

This disease is second in importance to melanose and stem-end rot caused by *Phomopsis citri*. It is the most serious fungus disease of the citrus nursery, where it attacks leaves and succulent twigs. In the orchard its activity is mainly confined to fruit and leaves.

Leaves are most susceptible in the very early stages of growth. They become entirely resistant by the time they reach half an inch in width.

Young grapefruits are extremely susceptible to infection immediately after the falling of the petals. They become progressively resistant until they reach immunity at a diameter of about three-fourths of an inch.

Scab infections are likely to occur whenever there is sufficient moisture at the time the parts are in a susceptible stage. Under such conditions infections developing in the hot, rainy summer months

are as severe as those occurring during the cool weather of spring or fall.

Citrus scab is caused by a definite fungus usually but erroneously referred to as *Cladosporium citri* Massee. It has none of the characters of Cladosporium Link. It has been confused with a common saprophyte in citrus lesions.

The causal fungus does not live over winter on mature fruit. It passes this period on affected leaves which act as foci of infection the following spring.

The citrus-scab fungus does not appear to be more virulent now than was the case a few years after its first introduction into America, nor are the various citrus varieties changing their former susceptibility.

There is no material difference in percentage or degree of infection that could reasonably be attributed to immunizing or sensitizing influences produced by the root stock on the scion.

Cumulative evidence including spraying experiments and orchard observations, goes to show that citrus scab can be controlled satisfactorily and economically. Scab in the nursery can be controlled readily by occasional applications of effective sprays.

Plain Bordeaux mixture as well as Bordeaux mixture plus oil emulsion is very effective against citrus scab, either in the nursery or in the orchard. Burgundy mixture is distinctly less effective than Bordeaux mixture, and ammonical copper carbonate solution is much less so.

Lime-sulphur solution is much less effective against this disease than is Bordeaux mixture. The other sulphur sprays are no more effective against citrus scab than is lime-sulphur solution.

Spraying after the smallest fruits have attained a diameter of three-fourths of an inch has no effect on the control of scab.

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CITRUS SCAB ON THE LEAVES OF GRAPEFRUIT, SATSUMA ORANGE, AND LEMON.

FIG. 1.—New flush of growth on grapefruit affected with scab. Blossoms have developed. (Photographed by Grossenbacher.) FIG. 2.—Effects of a moderate infection on leaves of the Satsuma orange. This disease is usually not especially conspicuous on the leaves of this variety. FIG. 3.—Citrus scab lesions resulting from artificial inoculation on a lemon leaf.

CITRUS SCAB ON GRAPEFRUIT LEAVES.

Distortion of the leaves is very frequently associated with scab infection.

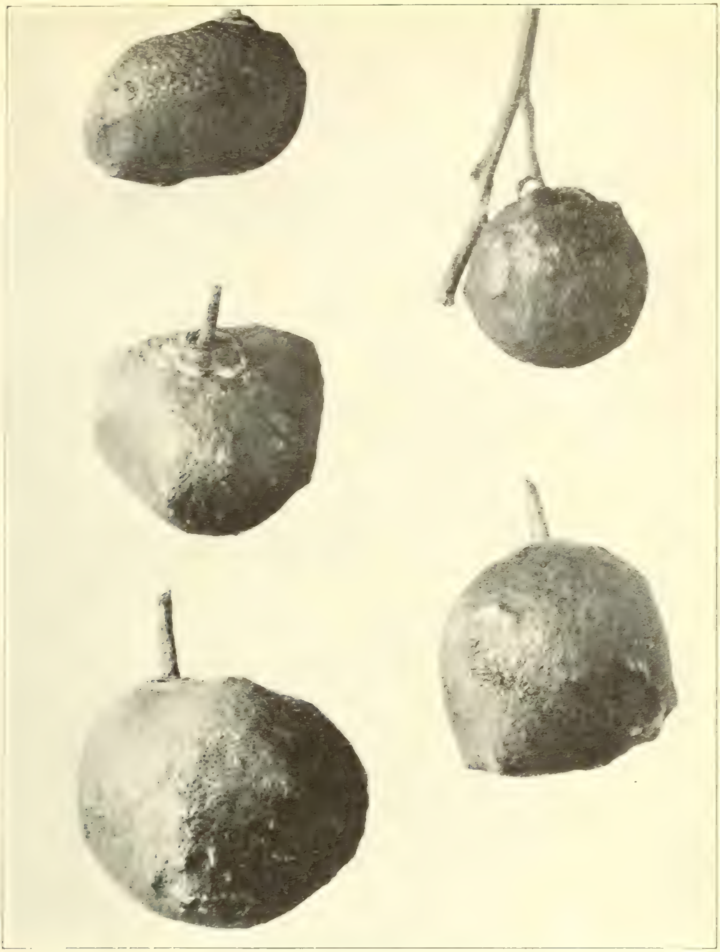


FIG. 1.—CITRUS SCAB ON HALL GRAPEFRUIT.

Fruits distorted to this extent usually drop in May or June. Should they reach maturity they would be graded as culls.

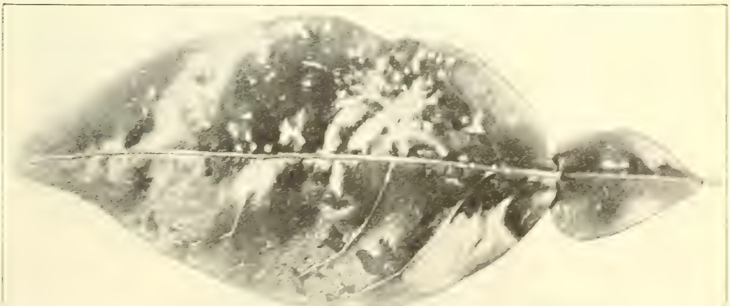


FIG. 2.—CITRUS SCAB ON LEAF OF GRAPEFRUIT.

Effects of artificial inoculations with the citrus-scab fungus.

CITRUS SCAB ON SOUR-ORANGE NURSERY STOCK.

The difference in size of these plants is due largely, if not solely, to the stunting effects of this disease.

FIG. 1.—CITRUS SCAB ON A SATSUMA ORANGE.

This is probably the most serious parasitic disease of this variety.

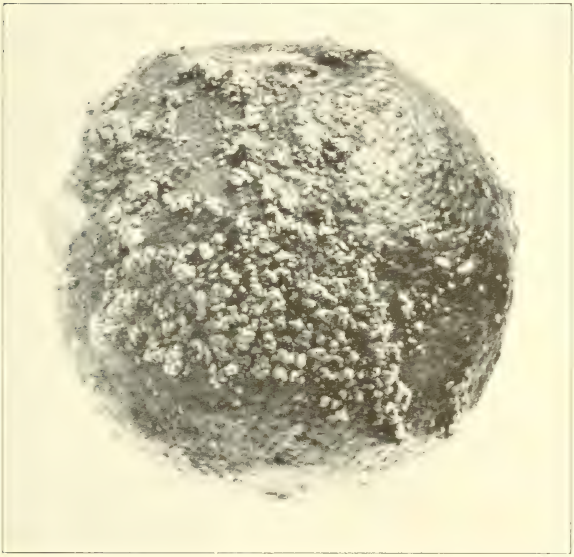
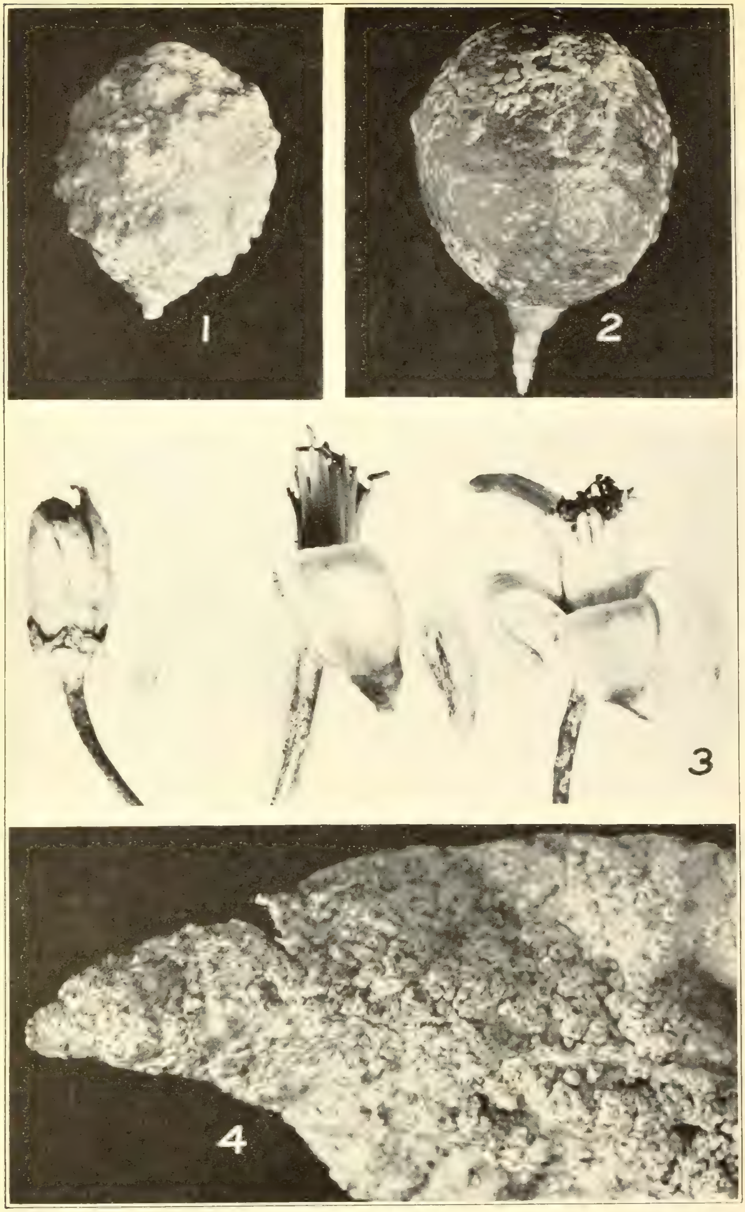


FIG. 2.—CITRUS SCAB ON A SOUR ORANGE.

The sour orange is of considerable economic importance. It is admirably adapted as a stock for heavy soils, and its fruit makes an excellent ade as well as a base for jellies, marmalades, etc.



CITRUS SCAB ON TANGELO, LEMON, GRAPEFRUIT, AND SOUR ORANGE.

FIG. 1.—Very severe attack of scab on tangelo. This fruit probably would not have reached maturity. (Natural size.) FIG. 2.—Characteristic scab lesions in immature lemon. (Natural size.) FIG. 3.—Lesions on stem and calyx of grapefruit flowers. FIG. 4.—Scab lesions on mature sour-orange leaf. × 3.

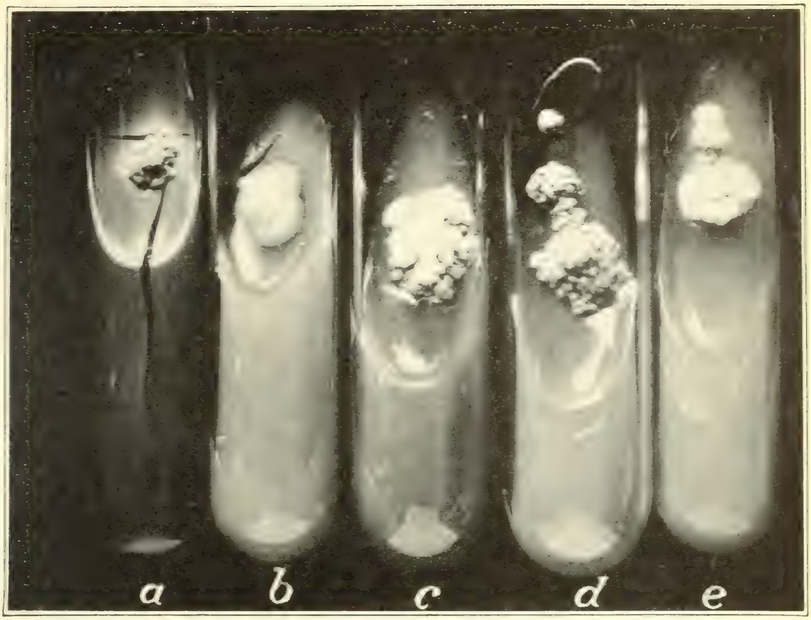


FIG. 1.—CULTURES OF THE CITRUS-SCAB FUNGUS.

Growth of 16 days on slants: *a*, On beef agar; *b*, on glycerin agar; *c*, on potato-dextrose agar; *d*, on Molisch's agar; *e* on tomato agar. This fungus varies greatly in culture. The growth characters in tubes *b* and *d* are not at all similar.

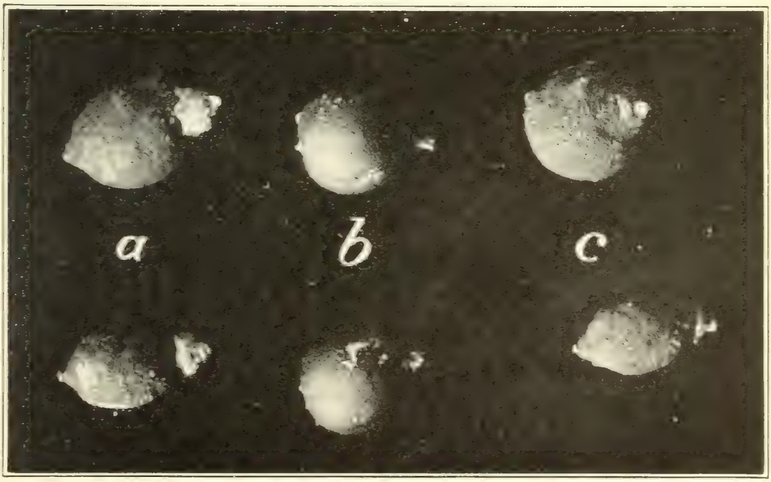


FIG. 2.—CITRUS SCAB ON UNUSUAL CITRUS FRUITS.

Effect on Chinese lemon (*a*); calamondin (*b*); Sour Rangpur lime (*c*).

FIG. 1.—CITRUS SCAB ON LEAVES AND STEM OF ROUGH-LEMON NURSERY STOCK.

This disease produces a severe stunting effect on small seedlings of susceptible species.

FIG. 2.—EXPANDING GRAPEFRUIT LEAVES.

On the left, the leaves are in the stage of growth most susceptible to scab; on the right, the larger leaves are no longer susceptible to infection. (Slightly reduced.)

FIG. 1.—TWIGS OF SOUR ORANGE AFFECTED WITH CITRUS SCAB.

These infections took place in southern Florida during the summer of 1920.

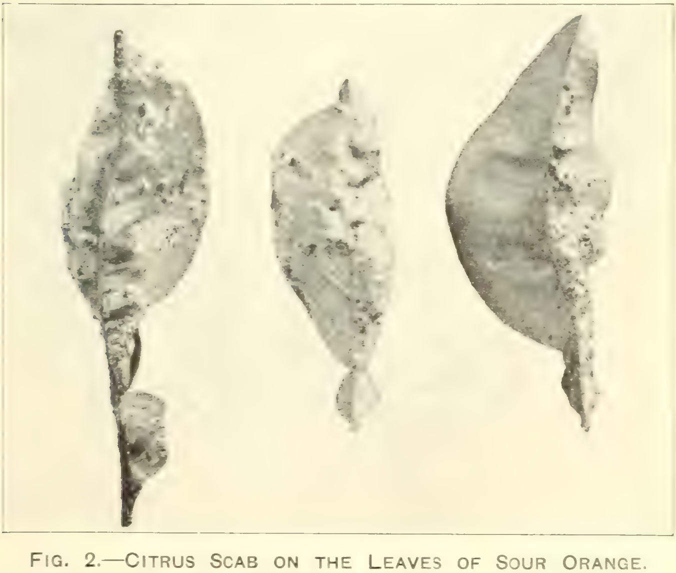


FIG. 2.—CITRUS SCAB ON THE LEAVES OF SOUR ORANGE.

These leaves expanded and became infected in the Government nursery at Orlando, Fla., during the summer of 1920.

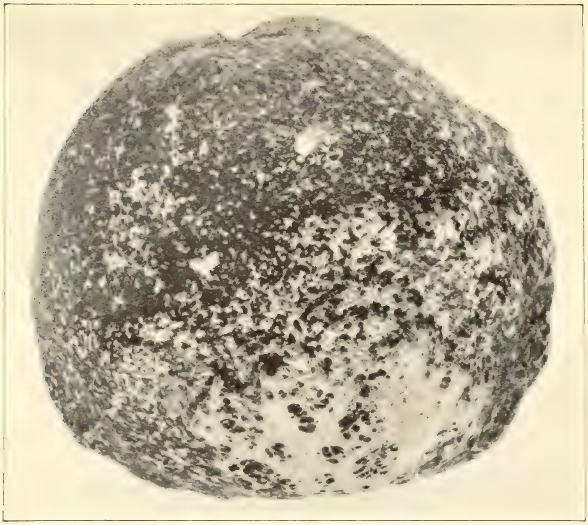
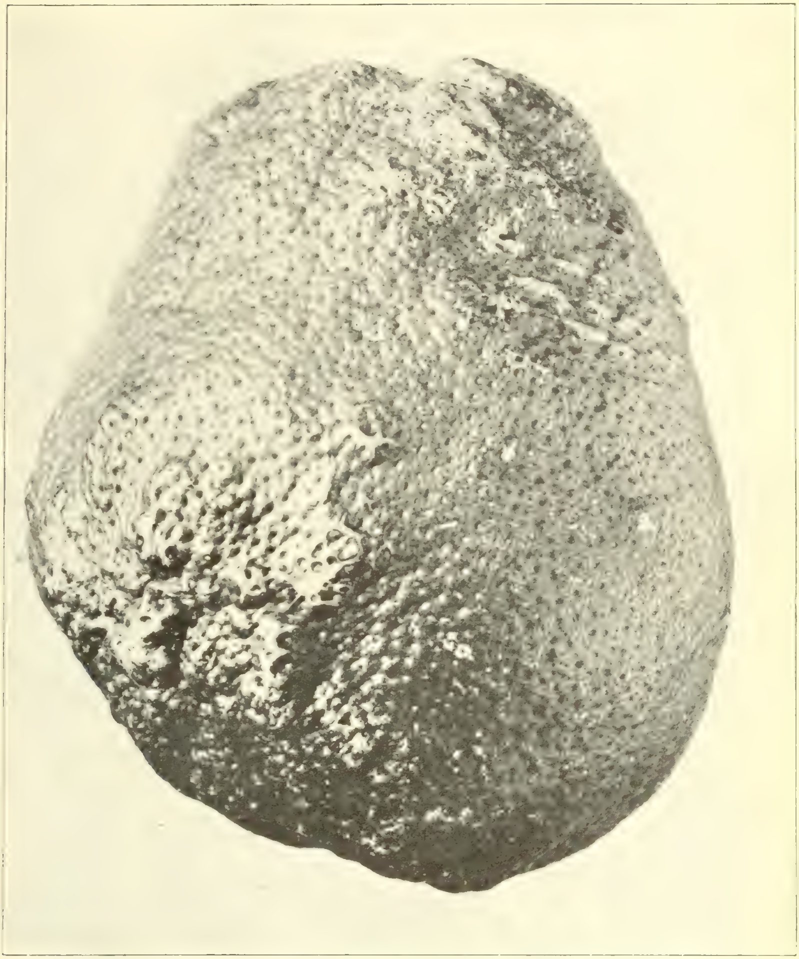


FIG. 1.—CITRUS SCAB ON IMMATURE GRAPEFRUIT.

Effects of a severe, general infection which occurred when the fruit was very young. (Natural size.) Note that the protuberances have flattened considerably. Such fruits usually fall before reaching maturity.

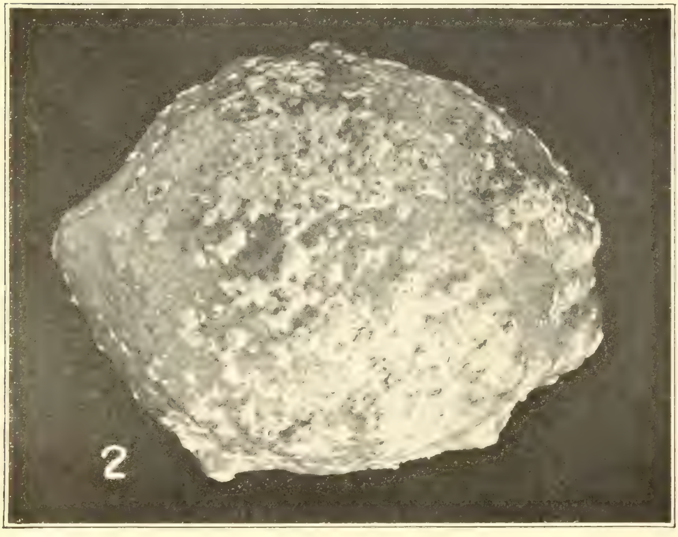
FIG. 2.—CITRUS SCAB ON GRAPEFRUIT.

Effects of a late infection on fruit which reached maturity.



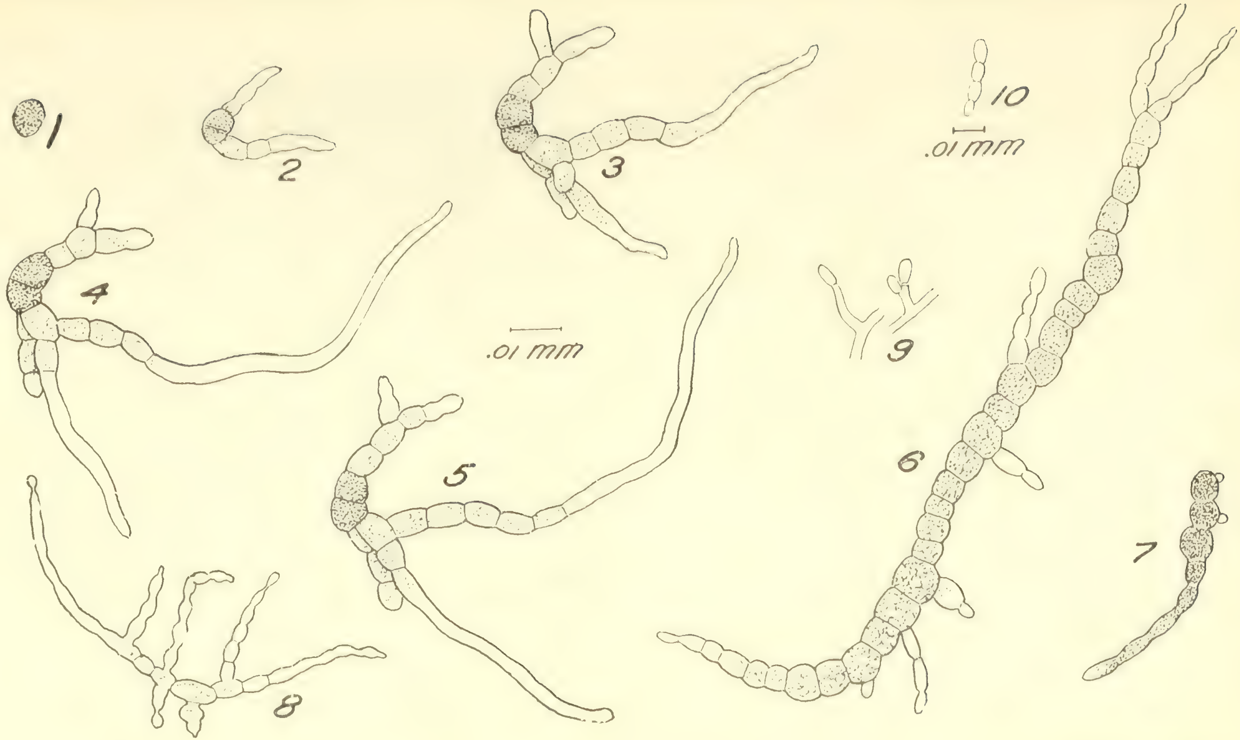
CITRUS SCAB ON GRAPEFRUIT SET IN JUNE.

Fruit set in June or during the rainy season usually becomes scabby, pear shaped, and is at best poor in quality. When such fruit is attacked by citrus scab the lesions do not flatten out as completely as is the case with spring-bloom fruit.



CITRUS SCAB ON TANGELO AND LEMON VARIETIES.

FIG. 1.—Effect on a mature Sampson tangelo. FIG. 2.—Effect on Eureka lemon. These species are extremely susceptible to this disease, which detracts largely from their value for commercial plantings.



GROWTH CHARACTERS OF THE CITRUS-SCAB FUNGUS.

FIG. 1.—Chlamydospore of the citrus-scab fungus. FIG. 2. Growth from chlamydospore after 24 hours at 20° C. FIG. 3.—Growth from chlamydospore after two days at 20° C. FIG. 4. Growth from chlamydospore after three days at 20° C. FIG. 5. Growth from chlamydospore after six days at 20° C. FIGS. 6 AND 7. Germinating chlamydospores. FIG. 8. Germination from comparatively young constricted mycelium after 48 hours at 20° C. FIG. 9.—Conidia of the citrus-scab fungus grown on corn-meal agar by Miss Anna E. Jenkins, of the Office of Pathological Collections. FIG. 10. Constricted young mycelium.

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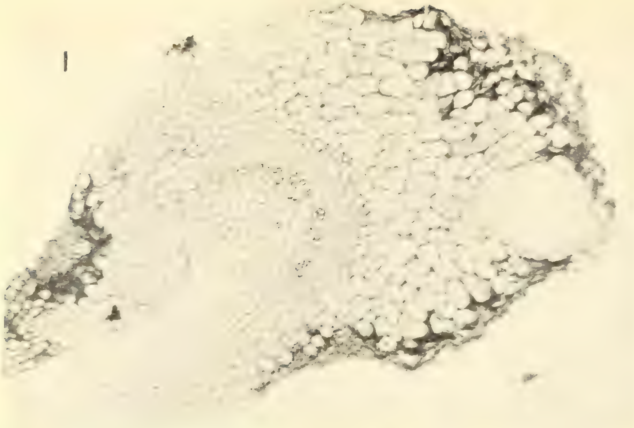

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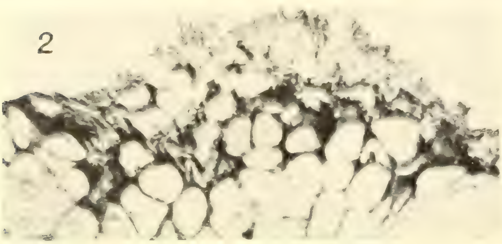

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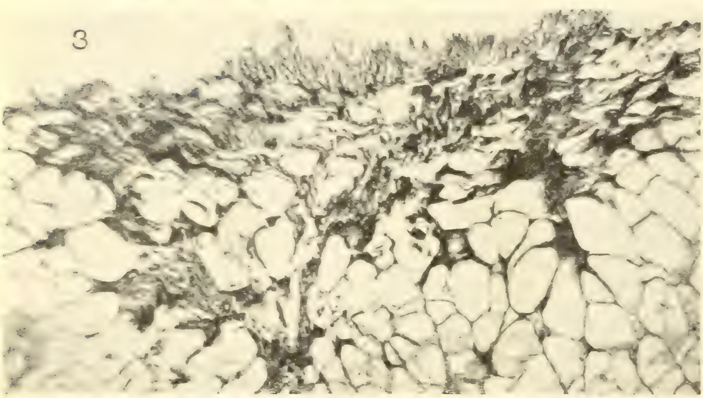

CITRUS SCAB ON THE LEAVES OF ROUGH LEMON.

FIG. 1.—Photomicrograph of cross section of emerging leaf infected with citrus scab. Three distinct lesions are seen on the lower or exposed surface. The arrangement of the leaf in the bud probably accounts for the relatively small number of lesions found on the upper surface of affected leaves. FIG. 2.—Photomicrograph of citrus-scab lesion on expanding leaf. Such lesions can sometimes be seen faintly with the unaided eye. The leaf tissue is affected to a depth of two or three cells, even before the leaf expands. Notice the stromatic mass of fungal hyphæ. FIG. 3.—Photomicrograph of a citrus-scab lesion on expanded leaf. This lesion, probably 2 months old, is being overrun by a saprophytic Cladosporium. The scab fungus penetrates the host tissue intercellularly for some distance.

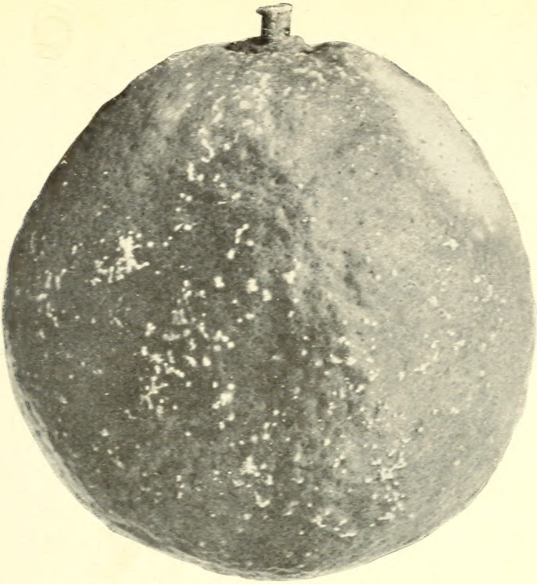

FIG. 1.—EFFECT OF ARTIFICIAL INOCULATION WITH THE CITRUS-SCAB FUNGUS ON GRAPEFRUIT.

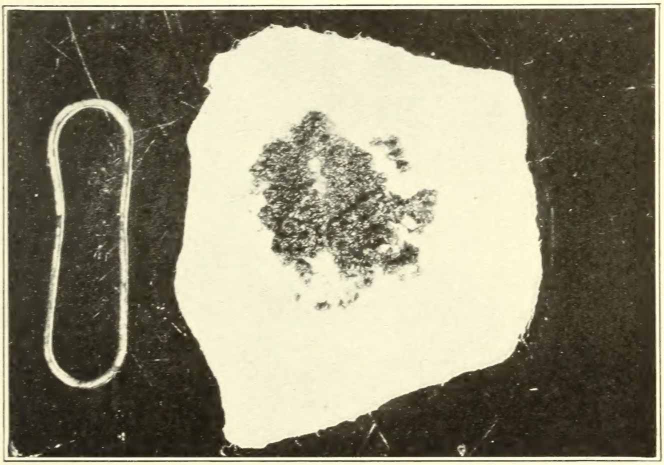

FIG. 2.—COTTON PAD AND INOCULUM SMEAR USED IN MOST INOCULATION EXPERIMENTS.

FIG. 1.—A KING OF SIAM TREE WITH WRAPPED INOCULATIONS AFTER WEATHERING A 2-DAY STORM.

This method of making inoculations has proved very satisfactory for outdoor work.

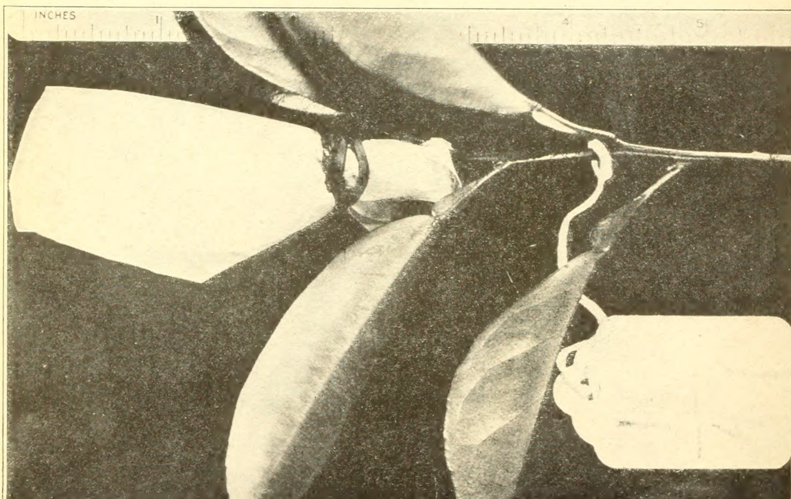

FIG. 2.—A WRAPPED INOCULATION.